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Effect of climate on 32-8560 cane grown on two different soils. Left to right: (1) on Makiki soil at Makiki; (2) on Makiki soil at Manoa; (3) on Manoa soil at Makiki; (4) on Manoa soil at Manoa.

FOURTH QUARTER 1941

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THE HAWAIIAN PLANTERS' RECORD

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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Composition of Sugar Cane Plants Grown in Deficient Nutrient Solutions:

In using leaves and sheaths as indices of the levels of the various nutrients in cane, it is necessary to know the effects of serious deficiencies not only upon the levels of N–P–K, but also upon sugars and water. In this study, the variety 31–2806 was grown in deficient nutrient solutions which included a complete nutrient solution as the control, and each of the remaining nine cultures was deficient in one of the following nine elements: nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, and boron.

Upon harvest the plants were separated into their various parts (see Fig. 1) and each part analyzed for moisture, carbohydrate, nitrogen, phosphorus, potassium, and calcium.

Of considerable importance is the fact that no matter what the deficiency from which the plant was suffering, the moisture level of the elongating cane sheaths correlated ($.821 \pm .109$) very well with the moisture level of the entire plant. Another correlation observed is that with the exception of the minus-iron culture, there is a good inverse correlation between the sugar level of the sheath and the quality ratio of the cane ($r = -.800 \pm .128$). Finally, each mineral deficiency had a marked effect not only on the total amount of N–P–K absorbed, but upon the balance among them.

Cane Growth Studies—Factors Which Influence Yields and Composition of Sugar Cane:

Further research concerned with some of the factors which influence yields and composition of sugar cane has identified certain interactions which are involved. Definite effects were measured from different soils, from different varieties, and from different levels of fertilization but these were all considerably modified by the differences in climatic influences, chiefly sunlight and temperature, under which the crops were grown.

Soil and Plant Material Analyses by Rapid Chemical Methods—III:

A gradual extension of the field in which rapid chemical methods of analysis (R.C.M.) are being applied has brought about the development of new procedures and the modification of some of the older ones for special purposes. These are described in detail. Ten years employment of R.C.M. by ourselves and agricultural workers in other countries has rendered it necessary to clarify a number of tables and explanatory matter in the two bulletins issued by this Experiment Station on the subject. The present paper is intended to record and classify all major developments in R.C.M. up to the end of 1941. It will be issued as Bulletin No. 53 of the Experiment Station, H.S.P.A. Agricultural and Chemical Series.

Composition of Sugar Cane Plants Grown in Deficient Nutrient Solutions*

By Harry F. Clements, J. P. Martin and S. Moriguchi

Any attempt to use the Index Method (1) in determining the fertilizer requirements of cane crops must be based upon a background of knowledge involving the behavior of the plants toward certain known nutritional circumstances. Although cane growing under field conditions will rarely suffer mineral deficiencies as acute as those observed in deficient nutrient solutions, the opportunity to study plants so produced was presented as a result of the plants grown at the Experiment Station H. S. P. A. Four varieties, H 109, 32–1063, 32–8560, and 31–2806, were grown in culture solutions as already described by Martin (6). He noted that some varieties manifested a much higher degree of tolerance to certain deficiencies than others and that varieties have different nutritional requirements. Further, Martin has already reported on the general reactions of the first three varieties (7). The variety 31–2806 was removed from the culture solutions December 18, 1940, and was used to obtain information regarding the composition of the different parts of plant with reference to reducing sugars, sucrose, acid-hydrolyzable carbohydrates, moisture, total nitrogen, potash, phosphorus, and calcium.

Experimental

Upon removal from the culture solutions, each plant was divided into its various parts (Fig. 1). Starting at the bottom of the stalk after the roots were removed and discarded, the millable cane was cut into three internode units. The lowest three internodes are called the "1st 3 internodes," the next three, the "2d 3 internodes," etc., up to the joint carrying a leaf. The green top representing the metabolically active part was then divided. Beginning with the spindle leaf as No. 1, the leaves were counted successively downward. The oldest leaves up to and including leaf No. 7 were removed from the cane and divided into blades (green-leaf blades) and sheaths (green-leaf sheaths). The piece of cane exposed by the removal of these leaves was then cut just below leaf No. 6, and labelled "green-leaf cane." Leaves 3, 4, 5, and 6 were next removed, and divided into blades (elongating cane blades) and sheaths (elongating cane sheaths). The piece of cane exposed by these removals was cut off just below leaf No. 2 and labelled "elongating cane." The remaining portion was then divided into two parts by cutting off five inches of the soft, white bottom (meristem) and leaving the top (spindle cluster). In some cases, because of the scarcity of material, it was necessary to combine some of these fractions.

The methods of analysis employed were the same as those used in previous studies (1).

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Results

When the plants were divided into their various parts, each part was weighed. These weights are recorded in Table I.

TABLE I

GREEN WEIGHTS OF PLANT PARTS

(Grams)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	217	57	177	131	195	103	195	136	129	169
2d 3 internodes	225	46	180	121	108	71	173	109	180	97
3d 3 internodes	176		140	141		43			168	
Top internodes	236		80	44		36	90		100	72
Green-leaf cane	140	10	48	40			103	28	170	28*
Elongating cane + meristem.	44		15	34		17	36	9	60	
Elongating cane sheaths	78	25	54	42		58	50	31	67	52*
Green-leaf sheaths	49		28	18			41	26	54	
Elongating cane blades	115	29	79	63		97	52	61	89	45*
Green-leaf blades	83		42	24			39	49	97	
Spindle cluster	97	14	43	58		75	23	27	96	70*
Total	1460	181	886	716	303	500	802	476	1210	533

* These weights are taken from the lalas, the original top having been killed.

An examination of Table I reveals the relative severity of the various deficiencies as measured by the actual growth made in each case. In all cases, there appear to have been an actual physiological deficiency strikingly revealed in the amount of leaf growth made. In Table II, the ratio of leaf weight of deficiency plants vs. the control plant produced in complete nutrient and the ratio of the total plant weight of deficiency plants vs. the control are recorded. Also reported in Table II is a statement regarding the leaf color range in culture.

TABLE II

DEFICIENCIES AND LEAF GROWTH

Nutrient culture	Ratio leaf weight deficiencies / Complete	Ratio total weight deficiencies / Complete	Leaf color range
Complete			Light green to dark green
—N	.146	.124	Yellow green
—P	.556	.605	Light green to green
—K	.491	.490	Light green to green
—Ca	0	.208	No leaves
—Mg	.583	.344	Yellow-green
—S	.380	.548	Yellow-green to light green
—Fe	.465	.327	White to yellow-green
—Mn	.956	.828	Yellow-green to light green
—B	0	.365	Dark green (lala leaves)

So far as N, P, and K deficiency effects are concerned, the total weight of the plant is rather closely related to the leaf weight. One might under field conditions

expect to find various levels of these materials affecting the leaf areas which in turn would affect the amount of cane weight produced. Of the remaining elements, the leaf weight ratios exceed total weight ratios in the cases of Fe, Mg, and Mn. Since Mg is a constituent of chlorophyll and Fe is essential to the formation of the pigment, it is understandable that deficiencies of these materials lower the efficiency of the leaves. The fact that Mn also falls into this category suggests its function as being at least somewhat related.

The remaining deficiencies, —Ca, —S, and —B, give leaf ratios below the total weight ratios. The effects of Ca and B deficiencies are so violent that the whole green tops are killed. The effects of S deficiency are mild by comparison.

In Table III are recorded the moisture contents of the various plant parts produced in the deficiency series.

TABLE III

MOISTURE CONTENT

(% Green Weight)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	68.2	73.7	68.4	74.0	72.3	79.6	72.3	69.9	66.7	79.3
2d 3 internodes	68.4	78.3	70.0	75.2	72.2	80.3	73.8	72.5	66.9	79.4
3d 3 internodes	69.3		73.6	75.1		82.6			69.6	
Top internodes	72.5		78.8	78.4		80.6	75.6		72.0	81.9
Green-leaf cane	79.3	95.0	85.4	78.8			79.6	82.1	79.7	85.7
Elongating cane and meristem	88.6		93.3	88.2		94.1	87.5	88.9	88.3	
Elongating cane sheaths	76.9	84.0	78.7	76.2		83.6	80.0	79.0	76.9	83.7
Green-leaf sheaths	75.5		78.3	77.8			78.1	80.8	74.1	
Elongating cane blades	71.3	72.4	70.2	69.8		72.2	71.2	72.1	71.4	76.7
Green-leaf blades	71.1		70.3	66.7			69.2	71.4	71.1	
Spindle cluster	75.3	78.6	77.9	75.9		78.7	78.3	77.8	77.1	78.6
Moisture per cent for whole plant	72.5	77.7	73.5	76.4	...	79.4	75.1	73.8	72.9	80.1

In general, it may be said that whatever differences exist in the moisture percentages of old tissues, they tend to be reduced in younger tissues. However, in most instances the level of moisture in the elongating cane sheaths serves as an index to the general moisture level of the whole plant. In only the case of —K is there a serious departure from this relationship. The correlation existing between the moisture level of the young sheaths and the moisture level of the entire plant is $+.821 \pm .109$.

Results of analysis of the various tissues for reducing sugars, sucrose and acid-hydrolyzable materials are reported in Tables IV, V, and VI, respectively.

TABLE IV

REDUCING SUGARS

(% Dry Weight)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	.4	1.6	.4	2.1	0.3	0.3	0.9	0.3	0.5	.6
2d 3 internodes	.4	1.8	.4	6.2	0.5	.2	1.5	1.2	.3	.6
3d 3 internodes	.6		.4	8.8		.3			.3	
Top internodes	.6		1.1	7.3		.3	4.5		.3	.6
Green-leaf cane	1.7		3.1	12.1			4.7	.3	2.6	2.0
Elongating cane and meristem	2.9		1.8	11.2		.6	10.1	.6	6.4	
Elongating cane sheaths	.6	.8	.9	7.6		.3	3.1	2.2	1.9	2.5
Green-leaf sheaths	.6		.4	6.1			1.7	1.4	1.0	
Elongating cane blades	.2	.7	.1	1.0		.2	.9	.2	.2	.2
Green-leaf blades	.3		.1	1.5			1.1	.3	.5	
Spindle cluster	1.6	1.5	.6	3.1		.5	1.1	.8	1.3	.9

TABLE V

SUCROSE

(% Dry Weight)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	36.7	46.2	41.8	42.7	50.0	28.5	37.3	26.4	39.7	37.4
2d 3 internodes	36.3	40.1	42.2	39.2	51.6	30.5	38.4	26.2	38.7	37.3
3d 3 internodes	37.1		39.5	32.0		25.7			40.3	
Top internodes	39.3		32.5	28.9		11.8	32.9		41.4	35.4
Green-leaf cane	33.3		18.0	20.8			25.5	26.6	32.3	15.0
Elongating cane and meristem	14.0		3.5	14.6		8.6	11.4	10.1	13.7	
Elongating cane sheaths	6.1	8.5	9.4	6.8		2.1	6.4	17.8	10.2	5.8
Green-leaf sheaths	6.0		9.4	8.0			14.6	12.8	8.1	
Elongating cane blades	4.8	3.6	3.4	4.8		5.0	3.3	5.3	3.6	2.7
Green-leaf blades	5.8		4.2	3.2			3.3	6.0	4.6	
Spindle cluster	4.4	4.4	4.0	3.7		2.9	4.0	4.7	4.1	2.6

TABLE VI

ACID-HYDROLYZABLE CARBOHYDRATE

(% Dry Weight)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	3.9	5.0	4.6	4.9	3.6	4.9	5.1	4.4	5.1	4.5
2d 3 internodes	4.7	5.4	4.9	4.8	4.1	4.7	5.1	4.3	5.1	4.7
3d 3 internodes	4.6		5.2	4.8		6.1			5.3	
Top internodes	5.3		5.6	5.6		7.0	5.6		5.7	4.9
Green-leaf cane	6.3		7.6	6.6			6.2	6.1	6.1	12.9
Elongating cane and meristem	11.1		4.0	10.8		11.1	13.8	12.5	11.1	
Elongating cane sheaths	16.2	19.5	19.6	17.7		17.1	19.1	15.8	18.3	18.5
Green-leaf sheaths	17.8		19.6	16.7			18.0	15.6	18.8	
Elongating cane blades	19.5	20.4	19.3	16.6		16.2	22.1	16.0	17.4	17.3
Green-leaf blades	18.1		18.7	17.3			20.1	16.0	18.4	
Spindle cluster	20.5	20.1	20.6	17.9		18.5	21.0	18.0	20.0	17.6

So far as the reducing sugars are concerned, the —K culture is the only one in which the reducing sugars are unusually high (2, 3). Whether this is due to the actual deficiency of potassium or to the increased absorption of calcium (see Table XI) remains to be determined.

Sucrose in the millable cane of the complete culture solution is not so high as usually obtains in the field, but is higher in the —N, —P, —Ca, and —Mn cultures. In the —Mg and —Fe cultures, the cane produces the lowest amount of storage sugar, while in the remaining cultures there is little difference.

So far as the acid-hydrolyzable carbohydrates are concerned, nothing of any moment appears in the data, except that the amount of this material in the cane is considerably lower than in cane grown under field conditions.

In Table VI are reported the data for the total sugars of the plant, representing the combined sucrose and reducing sugars. Physiologically, such a combination is justifiable since both forms are readily available to the plant for growth and since the two forms are so readily interconvertible (4, 5). Just what the factors are which affect the balance between the two in storage cane remains to be worked out.

TABLE VII

TOTAL SUGARS

(% Dry Weight)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	37.1	47.8	42.2	44.8	50.3	28.3	38.2	26.7	40.7	38.0
2d 3 internodes	36.7	41.9	42.6	45.4	52.1	30.7	39.9	27.4	39.0	37.9
3d 3 internodes	37.8		39.9	40.8		26.0			40.6	
Top internodes	39.9		33.6	36.2		12.1	37.4		41.7	36.0
Green-leaf cane	35.0		21.1	32.9			30.2	26.9	35.9	17.0
Elongating cane and meristem	16.9		5.3	25.8		9.2	21.5	10.7	20.1	
Elongating cane sheaths	6.7	9.3	10.3	14.4		2.4	9.5	20.0	12.1	8.3
Green-leaf sheaths	6.6		9.8	14.1			16.3	14.2	9.1	
Elongating cane blades	5.0	4.3	3.5	5.8		5.2	4.2	5.5	3.8	2.8
Green-leaf blades	6.1		4.3	4.7			4.4	6.3	5.1	
Spindle cluster	6.0	5.9	4.6	6.7		3.4	5.1	5.5	4.4	3.6
Calculated Q. R.	9.2	9.9	9.1	10.9	7.1	19.4	10.4	13.3	8.7	13.2

There appear in this table several correlations worth noting. The quality of the cane in all the deficiencies except —Fe, —B, and —Mg is about the same as the control, which means that the deficiencies are related for the most part to a decrease in growth activities and very slightly to the proportion of carbohydrate material used in growth or storage. Fe and Mg are both intimately connected with chlorophyll formation and, in addition, Fe is important in respiration; hence one can expect storage and sugar movement to be interfered with. Any element (such as Mg and Fe), which is involved in photosynthesis, is likely in its absence to affect storage adversely. Any element (such as Fe), which will interfere with respiration, is likely to affect the movement of sugar into the main storage tissue and will result in an accumulation of sugar in the sheath tissue. This, no

doubt, accounts for the high sugar values in the sheaths of the —Fe series. The poorer quality of the —B culture is related not to the amount of sugar in the cane, but rather to a higher moisture content. The high quality of the minus calcium culture fits with the observations made by Verret (9) that application of lime to cane under field conditions causes poorer juices.

Another observation worthy of note is that in all cases except —Mg, the level of the total sugars in the sheaths is higher than in the control, which suggests the relationship previously pointed out that any interference with the balance between carbohydrate production and utilization will be reflected in the level of sheath sugars. Thus, a reduction in growth without a corresponding reduction in photosynthesis will raise the level of sheath sugar. An increase in growth will lower the level of sheath sugars. A decrease in photosynthetic efficiency (—Mg) will obviously reduce the sheath sugar level. That the relationship between the sheath sugar level and the growth made is not more striking is probably caused by the advanced stages of disintegration of such cultures as —N, —K, etc.

The final observation to be made from Table VII is that with the exception of the —Fe culture there is a rather good inverse correlation between the quality ratio of the cane and the total sugar level of the elongating cane sheaths ($r = -.800 \pm .128$). Since a deficiency of iron affects the sugar translocation mechanism, it is reasonable to expect a blockage of sugar in the top portion and a lowering of the sugar level in the cane.

Mineral Composition

All the samples collected were subjected to analysis for total nitrogen, phosphorus, potassium, and calcium. The results are reported in Tables VIII to XI.

TABLE VIII

TOTAL NITROGEN

(% Dry Matter)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	1.06	.13	1.37	.51	1.13	1.08	1.45	1.04	.68	.98
2d 3 internodes	1.13	.25	1.12	.60	.87	1.21	1.05	1.21	.75	.73
3d 3 internodes	1.15		1.02	.66		1.30			.88	
Top internodes	.91		.87	.63		1.82	.93	1.4	.86	.60
Green-leaf cane	.68	.88	.94	.74			.86	1.46	.75	.79
Elongating cane and meristem	1.46		2.10	1.32		2.40	1.10	2.14	.60	
Elongating cane sheaths	.32	.33	.37	.51		.70	.45	.57	.36	.51
Green-leaf cane sheaths	.33		.28	.42			.39	.43	.32	
Elongating cane blades	.95	.78	.92	1.20		1.13	.57	.87	1.04	1.52
Green-leaf cane blades	1.02		.92	.94			.47	.84	1.10	
Spindle cluster	.76	.70	.86	1.12		1.26	.62	.94	.93	1.16

TABLE IX

PHOSPHORUS (P_2O_5)

(% Dry Matter)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	.41	.92	.02	.48	.98	.92	.46	.46	.37	.71
2d 3 internodes	.34	1.01	.06	.27	1.12	1.15	.46	.62	.27	.71
3d 3 internodes	.30		.07	.27		1.03			.25	
Top internodes	.27		.07	.32		1.24	.37		.27	.71
Green-leaf cane	.34	2.29	.14	.34			.34	.78	.41	
Elongating cane and meristem	1.10		.76	.85		1.03	.53	1.95	.87	1.21
Elongating cane sheaths	.32	1.33	.12	.53		1.61	.55	.94	.46	.62
Green-leaf cane sheaths	.27		.07	.48			.48	.39	.23	
Elongating cane blades	.39	1.67	.14	.64			.46	.90	.41	.64
Green-leaf cane blades	.32		.11	.76		.71	.37	.55	.34	
Spindle cluster	.57	.96	.27	.66		.90	.48	.90	.60	.66

TABLE X

TOTAL POTASSIUM (K_2O)

(% Dry Matter)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	.75	1.91	.65	.05	1.73	1.61	1.13	1.36	.74	2.18
2d 3 internodes	.93	2.93	1.17	.16	2.94	2.04	1.52	2.17	.81	2.28
3d 3 internodes	1.13		1.99	.22		1.96			1.04	
Top internodes	1.66		3.03	.06		2.20	1.77		1.46	3.12
Green-leaf cane	2.69	6.74	4.22	.11			2.44	2.55	2.49	3.79
Elongating cane and meristem	5.67		7.95	1.23		5.70	3.70	5.23	5.52	
Elongating cane sheaths	3.05	4.79	3.90	.29		5.07	3.61	4.69	3.21	4.01
Green-leaf cane sheaths	2.76		2.69	.30			3.06	3.01	2.43	
Elongating cane blades	2.76	3.01	2.12	.38		2.88	1.84	3.25	2.25	6.16
Green-leaf blades	2.60		2.38	.18			1.67	3.29	2.18	
Spindle cluster	2.98	3.18	2.77	1.37		3.37	2.24	1.73	2.96	3.05

TABLE XI

TOTAL CALCIUM (Ca)

(% Dry Matter)

	Complete	—N	—P	—K	—Ca	—Mg	—S	—Fe	—Mn	—B
1st 3 internodes	.04	.04	.05	.10	.02	.09	.06	.09	.06	.06
2d 3 internodes	.06	.06	.08	.10	.02	.16	.06	.12	.04	.08
3d 3 internodes	.06		.10	.14		.22			.06	
Top internodes	.07		.14	.18		.30	.08		.07	.12
Green-leaf cane	.09	.450	.23	.20			.11	.24	.10	.21
Elongating cane and meristem	.24		.10	.42		.32	.23	.36	.29	
Elongating cane sheaths	.14		.19	.38		.73	.16	.22	.15	.18
Green-leaf cane sheaths	.17		.22	.36			.18	.24	.20	
Elongating cane blades	.23		.27	.74		.46	.31	.32	.26	.25
Green-leaf blades	.46		.41	.94			.56	.83	.54	
Spindle cluster	.12		.17	.31		.28	.18	.19	.15	.16

There are two general ways of evaluating mineral compositions of plants. In the first case, each element is looked upon as an entity in relation to the dry matter of the various tissues of the plant and is therefore treated separately. In the second case, the three elements most commonly deficient under field conditions, N, P, and K, are looked upon as inseparable and are therefore combined into an N–P–K unit (8) and examined not only on the basis of the total amount of the three (intensity) but also upon the basis of the relative amounts of each (quality) in the young leaves. Both approaches will be followed in this paper.

In Table VIII, the nitrogen compositions of the various tissues of plants produced in the culture series are reported. The amounts of nitrogen in the top portions of the plant grown in the complete nutrient solution are very similar to those produced under field conditions. However, the nitrogen in the cane is about ten times higher than that associated with 31–1389 produced at Waipio. Such a fact means that the plants in the complete nutrient solution were absorbing much more of the element than they could use. In the minus-nitrogen culture, it is clear that deficiency is shown throughout the plant, although the plant maintains a disproportionate amount of nitrogen in its tops at the expense of the nitrogen in the cane. The interpretation would be that it removes nitrogen from the old tissues and uses it in the young tissues. Deficiencies of phosphorus and magnesium seem to result in a slight accumulation of nitrogen in the various tissues, while deficiencies of sulphur and iron result in normal nitrogen levels in the old tissues but reduced amounts in the leaf tissues. Deficiencies of manganese and potassium result in lower nitrogen levels in the cane but nearly normal levels in the tops.

Phosphorus: The phosphorus composition of the various tissues is reported in Table IX. The P_2O_5 content of the various tissues of the plant produced in the complete nutrient solutions is somewhat higher than that found in a field-grown crop. As in the case of nitrogen, the P_2O_5 content of the plant produced in the —P solution is relatively much lower in the old cane than in the tops. Plants grown in —N, —Ca, —Mg, —Fe and —B contain a higher percentage of P_2O_5 than does the normal plant. —K does not affect the P_2O_5 composition nor does —Mn. The —S culture has increased the proportion of P_2O_5 contained in the tissues.

Potassium: The level of potash in the plant grown in the complete nutrient solution is somewhat higher than found in field-grown cane, but the distribution of this material in the various plant parts is the same. The percentage composition of potassium is materially increased in the —N, —Ca, —Mg, —Fe and —B series. —P seems to result in an accumulation of potassium in the young portion of the stem without affecting the composition in other parts. —S, on the other hand, causes a slight accumulation in old cane and sheaths but a reduction in the young tissues. Manganese deficiency does not appear to affect the potassium content of the plant.

Calcium: The calcium content of the various tissues of the control plant is remarkably similar to that found in field-grown plants. The —K, and —Mg plants have a calcium content considerably higher than normal, while —Fe plants are slightly above the control in their calcium composition. Deficiencies of phosphorus, manganese, boron, sulphur do not affect the calcium composition. The minus

nitrogen plant has normal amounts of calcium in the old cane but very high amounts in the young cane. Lack of material made analysis of the green tissues impossible.

Turning now to the second method of analysis (8), the amounts of nitrogen (N), phosphorus (P_2O_5), and potash (K_2O) in the elongating cane leaves of the various cultures are shown in Table XII. In the last column, the intensity factor which is the sum of columns 2, 3, and 4 is reported for each culture.

TABLE XII

QUANTITATIVE EVALUATION OF THE N–P–K UNIT

(% Dry Weight—Young Leaves)

Culture	% Nitrogen (N)	% Phosphorus (P_2O_5)	% Potassium (K_2O)	Intensity
Complete	.95	.39	2.76	4.10
—Nitrogen	.78	1.67	3.01	5.46
—Phosphorus	.92	.14	2.12	3.18
—Potassium	1.20	.64	.38	2.22
—Calcium	...	...	...	
—Magnesium	1.13	.71	2.88	4.72
—Sulphur	.57	.46	1.84	2.87
—Iron	.87	.90	3.25	5.02
—Manganese	1.04	.41	2.25	3.70
—Boron	1.52	.64	6.16	8.32

From the viewpoint of the nutritional intensity, it is clear that all the treatments had a tremendous effect on the amounts of the materials (N–P–K). Some of the deficiencies caused a material increase in salt absorbed (—N, —Mg, —Fe, —B) while others caused a decrease (—P, —K, —S, —Mn). The average intensity factor for the field-grown crop of 31–1389 was 2.90 at Waipio and 3.285 at Kailua, while that of the control in this series was 4.10 showing a considerably greater intensity in the solution-grown plants.

The qualitative evaluation of the N–P–K unit is shown in Table XIII. To arrive at this value, each material, N, P_2O_5, and K_2O, is converted into milliequivalents and is expressed on the basis of a hundred units. Thus, the sum of each N–P–K unit quality equals 100.

TABLE XIII

QUALITATIVE EVALUATION OF THE N–P–K UNIT

	N	P_2O_5	K_2O	Intensity factor from Table XII
Complete*	10.09	2.46	87.45*	4.10
—Nitrogen	7.26	9.19	83.55	5.46
—Phosphorus	12.34	1.13	86.53	3.18
—Potassium	44.24	13.97	41.89	2.22
—Calcium	....	....	....	...
—Magnesium	15.78	5.88	78.35	4.72
—Sulphur	9.00	4.30	86.70	2.87
—Iron	7.84	4.80	87.36	5.02
—Manganese	13.01	3.03	83.96	3.70
—Boron	7.49	1.87	90.64	8.32

* The quality of the N–P–K unit of field-grown 31–1389 is (N) 18.17, (P_2O_5) 3.05, and (K_2O) 78.78. at Waipio and (N) 16.58, (P_2O_5) 2.09 and (K_2O) 81.33 at Kailua.

Fig. 1

Fig. 1. A sugar cane stalk of the variety 32–8560 separated into its various parts. These parts were traced on a large sheet of paper and the tracing photographed. Leaf No. 1 in the drawing was the spindle leaf of the intact plant and the other leaves were counted progressively downward. The small leaves within No. 1 cannot be seen in the intact plant since they are enclosed by the spindle leaf. The horizontal lines across leaves 2, 1 and those within represent the width of each of the leaves when fully unrolled. Since the drawing was made to scale, the length of the blades and sheaths of the leaves as indicated is a true indication of growth made. Thus, although the blade of leaf No. 1 has nearly reached its full length, the sheath has attained only a small fraction of its length. The sheath of leaf No. 2 is about half-grown and that of leaf No. 3 has nearly completed its growth.

The position which each leaf occupied on the stem is indicated by the broken horizontal line. The internodes below the attachment of leaf No. 6 seem to have attained their full length. The four internodes above are in various stages of elongation. At the very tip of the stem is the meristem.

In the studies reported in this paper, a stalk is taken and the dry-leaf cane is cut off from the green top just below the node carrying the last living leaf. In the case of the figure, that was at the node of leaf No. 10. The dry cane is further divided into three internode units beginning from the bottom.

The green top is divided into several parts as follows: The green leaves are removed up to and including leaf No. 7. (The spindle leaf is No. 1, and the others are numbered downward.) Although the number of leaves between No. 7 and the oldest varies, in the figure, leaves 7, 8, 9, and 10 would constitute the sample. These leaves are then separated into blades and sheaths. The blades of these leaves are called green-leaf blades and the sheaths, green-leaf sheaths. The stalk which has been exposed in removing these leaves is cut off just below the node of leaf No. 6. The sample is called green-leaf cane. It is to be noted that the internodes of this sample have reached their full length. Frequently, however, the upper internodes of this sample have yet to complete the growth in diameter.

Leaves 6, 5, 4, and 3 are next removed and separated into blades and sheaths. The blades are spoken of as the elongating cane blades and the elongating cane sheaths, respectively. The stem exposed by the removal of these leaves is cut off just below Joint No. 2 and is labeled elongating cane. The blades and sheaths are the critical tissues used to determine the levels of the various materials within the plant. The elongating cane sample is so-called because it is in this region the vertical elongation is taking place.

The material which remains now is made up of leaves Nos. 2 and 1 and the enclosed leaves as well as the very tip of the stem. About five inches of the base are removed and called the meristematic material, and the remaining upper part is called the spindle cluster.

The data in Table XIII indicate certain relationships which are worthy of note. The amounts of the three nutrients in the control are somewhat lower in nitrogen and higher in potash than in field-grown plants, but about the average with respect to phosphorus. It should be remembered, however, that the intensity of nutrition for the controls is considerably greater than for field-grown plants. Nitrogen deficiency increases the intensity factor and increases the absorption of phosphorus many times. Phosphorus deficiency reduces the intensity factor but disturbs the quality only through a reduction in P_2O_5. Potassium deficiency causes an enormous reduction of the intensity factor by its own absence, but greatly increases the balance of both phosphorus and nitrogen. Magnesium deficiency increases the intensity factor, and also increases the nitrogen and phosphorus portion of the N–P–K unit. Sulphur deficiency causes a large reduction in intensity and an increase in phosphorus at the expense of nitrogen in the unit. Iron deficiency affects the N–P–K nutrition by increasing the intensity factor and causes an increase in the relative amount of phosphorus at the expense of nitrogen. Manganese deficiency results in a reduced intensity factor, although within that reduction there is a relative increase of nitrogen and phosphorus at the expense of potash. Boron deficiency causes a doubling of the intensity factor and also a proportional increase in the amounts of potassium at the expense of phosphorus and nitrogen.

Summary

1. Plants of the variety 31–2806, after being grown in various deficiency solutions, were subjected to analysis for moisture, reducing sugars, sucrose, total sugars, acid-hydrolyzable carbohydrates, total nitrogen, potash, phosphorus and calcium.

2. All the deficiencies have marked effects in the amount of leaf growth produced. —N, —P, and —K produce reductions in leaf growth which are very nearly reflected in the total amount of growth made.

3. Considerable differences exist in the moisture content of plants produced in the various cultures. In each case, the moisture content of the young leaf sheath is a good index to the general moisture status of the whole plant.

4. Reducing sugars are low in all but the —K culture. Sucrose is highest in the cane of the —Ca culture. Acid-hydrolyzable carbohydrates show little variation among the cultures.

5. The quality ratios of the —Mg, —B, and —Fe were very poor. In the other cultures, there were small variations. The correlation between the quality ratio and the total sugar level of the young sheaths, except for the —Fe culture, was very good.

6. The influences of the various deficiencies on the amounts of N, P, and K found in the various tissues are presented.

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Cane Growth Studies

Factors Which Influence Yields and Composition of Sugar Cane

By R. J. Borden

Our desire for facts concerned with the various influences which affect cane yields and its composition has been the motive for another study of the effects of climate, soil, varieties, and fertilization.

In 1936 we reported* a dominating effect of climate upon the growth and plant crop yields of three sugar cane varieties, each grown on two different soil types, and all duplicated under two distinctly different climatic environments. Subsequently we harvested four ratoon crops from these same plantings and secured verification for much of the data originally reported. Since these data have not been reported collectively, we offer them in summary form in the following tables, but before doing so we should like to present again briefly the plan and conditions under which these studies have been conducted.

The Plan: Two different climatic environments were used, with a duplicated plan installed at each location. At the Makiki station where the elevation is only 40 feet above sea level, bright sunny days with relatively few rainy days are the rule, whereas at the 650-foot elevation of the Manoa substation there are many rainy days and less than 50 per cent of the sunlight received at Makiki. Maximum temperatures at Makiki are about 4 degrees higher than at Manoa but there is not much difference in the minimum temperature. Table I shows the comparative weather conditions which have been measured while these studies were underway.

Semi-protection from heavy winds and generally adequate irrigation were supplied so that variations in these two factors would not become depressive growth-effect factors and complicate the interpretation of the results. Hence we were chiefly concerned with the effects of the environmental factors of sunlight and maximum temperatures.

TABLE I

COMPARATIVE WEATHER CONDITIONS FOR ACTUAL GROWING PERIODS OF CROPS

Crop	Total inches rainfall		No. of days with rain exceeding ½ inch		Mean minimum temperature		Mean maximum temperature		Total day-degrees	
	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa
Plant—1935	47	199	20	99	67.5	67.4	84.6	80.2	6445	4488
1st ratoon—1936	44	182	21	110	68.1	66.6	83.0	77.8	4738	2959
2nd ratoon—1938	46	214	20	165	69.1	68.0	83.1	78.9	4942	3346
3rd ratoon—1939	39	197	18	122	69.7	67.3	82.8	78.8	4699	3394
4th ratoon—1940	38	173	10	113	63.2	60.9	82.9	78.9	4504	3428
Plant—1941	18	140	3	86	69.1	67.4	83.8	80.2	5321	3926

* Borden, R. J., 1936. Cane Growth Studies—The Dominating Effect of Climate, The Hawaiian Planters' Record, 40: 143–156.

Well-mixed soil from each of two sources placed in large 2′ x 2′ x 2′ concrete tubs provided the medium in which 3 cane varieties—H 109, Striped Tip, and POJ 2878—were originally planted in October 1934 at both locations. The Makiki soil, an alluvial chocolate-brown loam of fine structure, when wetted takes up water and also drains somewhat slowly, and packs quite firmly but without cracking as it dries. It has a slightly alkaline reaction and is well supplied with available phosphates, potash, and calcium; its content of organic matter is not high and its available nitrogen content is quite low. By contrast the Manoa soil, a residual yellow-brown silty loam, has an excellent granular structure that makes it porous and well drained. Its reaction is quite acid and its content of replaceable bases low. It is quite high in its organic matter content, contains a fair amount of available nitrogen, but has high phosphate-fixing properties; hence, to insure an adequate supply of phosphate in this Manoa soil, a heavy application of rock phosphate was mixed in under the seed before the original plantings were made.

All treatments were installed in triplicate, and analytical and yield data given hereafter include the measurements from all three tubs of each treatment. Adequate fertilization from ammonium sulphate, superphosphate, and muriate of potash was given frequently and similarly to all three varieties on both soils at each location. In addition, a supplementary series with POJ 2878 only was inadequately fertilized with only one fourth as much NPK as the adequately fertilized series received.

Five crops were harvested from the original plantings, as follows:

PROJECT A-105-NO. 43—CROPS HARVESTED

No.	Crop cycle	Year	Started	Harvested	Growing period
1	Plant crop	1935	Sept. 28, 1934	Dec. 14, 1935	442 days
2	1st ratoon	1936	Dec. 14, 1935	Dec. 16, 1936	368 "
3	2nd ratoon	1938	*April 9, 1937	April 22, 1938	376 "
4	3rd ratoon	1939	April 23, 1938	April 20, 1939	362 "
5	4th ratoon	1940	April 21, 1939	May 7, 1940	380 "

* Re-started after cutting back.

The Effects of Climate: The effects of climate are summarized in Table II; and discussed thereafter.

It is immediately apparent that the differences in climate have had definite effects. Cane Yields, quality (Y%C), and sugar yields have been consistently and considerably greater under the more favorable growing conditions at Makiki, and this generalization has apparently held true regardless of soil or cane variety, thus indicating the dominating effect of climate on yields.

The effect of climate on the percentage of phosphate in the crusher juices was not significant, but the canes grown at Manoa, regardless of soil, did have a significantly greater potash concentration than duplicates grown at Makiki.

It is doubtful whether the effect of climate on the pH of the soils at each harvest was significant, although it appeared for the first two crops that the soils cropped at Manoa had become more acid than duplicates at Makiki.

The data in Table II contain other items of interest. The higher yields from the plant crop are most likely due to the fact that it was two months older than the ratoons. The lower cane yields of the third and fourth ratoons may have been due

TABLE II

EFFECTS OF CLIMATE

Combined data from 3 replicates of 3 varieties, each grown in 2 soils, with adequate fertilization; Average of 18 pots

Crop	Lbs. cane grown at		Y%C grown at		Lbs. sugar grown at		% P_2O_5 in juice grown at		% K_2O in juice grown at		pH of soil at harvest grown at	
	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa
Plant—1935	77	30	11.7	8.6	8.9	2.7	.062	.071	.16	.21	5.8	5.4
1st ratoon—1936	73	24	10.2	7.8	7.5	1.9	.056	.055	.13	.17	5.8	5.3
2nd ratoon—1938	67	23	11.9	9.1	8.0	2.1	.064	.064	.10	.18	5.0	5.0
3rd ratoon—1939	63	23	9.8	8.4	6.2	1.9	.067	.073	.08	.15	5.1	5.2
4th ratoon—1940	66	21	12.1	9.4	8.1	2.0	.077	.081	.03	.11	4.8	4.5
Averages	69	24	11.1	8.7	7.8	2.1	.065	.069	.10	.16	5.3	5.1

TABLE III

EFFECTS OF SOIL

Combined data from 3 replicates of 3 varieties, each grown in 2 climates, with adequate fertilization; Average of 18 pots

Crop	Lbs. cane Soil		Y%C Soil		Lbs. sugar Soil		% P_2O_5 in juice Soil		% K_2O in juice Soil		pH of soil at harvest* Soil	
	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa	Makiki	Manoa
Plant—1935	47	60	10.6	9.7	5.4	6.3	.101	.032	.25	.12	6.1	5.1
1st ratoon—1936	45	53	9.3	8.7	4.8	4.9	.085	.025	.21	.09	6.4	4.7
2nd ratoon—1938	41	49	10.3	10.6	4.8	5.6	.093	.035	.17	.11	5.4	4.6
3rd ratoon—1939	37	49	9.1	9.1	3.5	4.7	.095	.045	.15	.08	5.5	4.8
4th ratoon—1940	38	49	10.6	10.9	4.3	5.8	.101	.057	.08	.06	4.8	4.5
Averages	42	52	10.0	9.8	4.5	5.4	.095	.039	.17	.09	5.6	4.7

* When the soils were originally potted the pH measurements were 7.2 for the Makiki soil and 5.4 for the Manoa soil.

to some rat damage at Manoa. However, it is not apparent that cane yields were seriously affected by continued cropping from potted soils, and certainly the sugar yields from the fourth ratoons were not significantly less than from previous ratoons grown at either Makiki or Manoa.

It would be interesting to know why the Y%C has been so variable from the second, third, and fourth ratoons which had approximately the same calendar growing periods, and which were apparently similarly influenced, *i.e.*, at both locations the 1939 crop had the lowest Y%C, the 1940 crop the best Y%C, with the 1938 crop Y%C figures being intermediate.

The per cent K_2O in the crusher juice shows a marked decrease in each successive crop at both locations. This decrease has occurred in spite of the fact that heavy potash fertilizer applications were made monthly on both soils throughout each cropping period. We have no satisfactory explanation for this decrease.

The effect of continued cropping also shows in the increased soil acidities that were measured.

The Effects of Soil: In Table III, we have summarized the effects of soil.

Although not as great as the effects of climate, it is interesting that the Manoa soil which has not been considered a "good" producing soil has consistently grown more cane and sugar than the Makiki soil. We believe this may be due to its superior physical characteristics which provide better aeration for root growth.

It is doubtful whether the cane quality (Y%C) has been influenced by the differences between the two soils which were used. In the first two harvests it was believed that the Makiki soil had produced cane with a better sugar content, but this was not verified in the subsequent three harvests.

There is no question, however, but that cane grown on the Makiki soil has had a higher concentration of both phosphate and potash in the crusher juices than that grown on Manoa soil, in spite of identical fertilization with phosphate and potash (except for the extra raw rock phosphate which was mixed into the Manoa soil before planting in 1934).

The Manoa soil has become still more acid than the Makiki soil; it shows a net loss of 275 acidity units* as compared with a net loss of 161 for the Makiki soil in less than 6 years. This is probably the effect of the heavy applications of ammonium sulphate which have been continued while the crops were growing. And yet apparently this increased acidity has not markedly reduced its ability to give satisfactory crops, for we do not find that comparable ratoons have given differences in sugar yields that are proved effects from soils which produced them.

The Effects of Varieties: Yields and crusher juice analyses from the three cane varieties which were studied are given in Table IV:

*

Time	Makiki soil		Manoa soil	
	pH	Acidity units	pH	Acidity units
Before planting (1934)	7.2	+ 1.0	5.4	— 40
After 4th ratoon (1940)	4.8	— 160.0	4.5	— 315
Difference		— 161		— 275

TABLE IV

EFFECTS OF VARIETIES

Combined data from 3 replicates on 2 soils, each under 2 climates with adequate fertilization;
Average of 12 pots

Crop	Lbs. cane			Y%C			Lbs. sugar			% P_2O_5 in juice			% K_2O in juice		
	H 109	Str. tip	POJ 2878	H 109	Str. tip	POJ 2878	H 109	Str. tip	POJ 2878	H 109	Str. tip	POJ 2878	H 109	Str. tip	POJ 2878
Plant	64	46	52	10.0	9.9	10.0	7.2	4.8	5.5	.049	.085	.058	.15	.18	.22
1st ratoon	57	45	44	7.8	9.9	9.2	5.0	4.8	4.3	.037	.079	.051	.12	.15	.18
2nd ratoon	51	38	46	10.2	10.2	11.0	5.7	4.1	5.5	.039	.097	.057	.11	.15	.16
3rd ratoon	53	31	45	8.9	9.1	9.2	4.9	2.9	4.4	.045	.104	.060	.08	.12	.14
4th ratoon	53	32	45	10.7	10.0	11.5	6.2	3.4	5.6	.045	.109	.083	.05	.08	.09
Averages	56	38	46	9.5	9.8	10.2	5.8	4.0	5.1	.043	.095	.062	.10	.14	.16

TABLE V

EFFECT OF ADEQUATE FERTILIZATION

Combined data from 3 replicates on 2 soils, each under 2 climates with variety POJ 2878 only;
Average of 12 pots

Crop	Lbs. cane		Y%C		Lbs. sugar		% P_2O_5 in juice		% K_2O in juice		pH of soil at harvest	
	Adeq. fertilized	Inadeq. fertilized	Adeq. fertilized	Inadeq. fertilized	Adeq. fertilized	Inadeq. fertilized	Adeq. fertilized	Inadeq. fertilized	Adeq. fertilized	Inadeq. fertilized	Adeq. fertilized	Inadeq. fertilized
Plant	52	25	10.0	11.7	5.5	3.0	.058	.080	.22	.18	5.9	5.9
1st ratoon	44	23	9.2	10.8	4.3	2.6	.051	.064	.18	.18	5.5	6.2
2nd ratoon	46	26	11.0	10.0	5.5	2.7	.057	.062	.16	.16	5.0	5.7
3rd ratoon	45	21	9.2	8.5	4.4	1.9	.060	.066	.14	.13	5.1	5.8
4th ratoon	45	20	11.5	11.9	5.6	2.4	.083	.088	.09	.09	4.7	5.7
Averages	46	23	10.2	10.6	5.1	2.5	.062	.072	.16	.15	5.2	5.9

Regardless of soil or of environment, H 109 has been the best producer of cane and sugar, but there were several crops in which the sugar yields from POJ 2878 were not significantly poorer; this was due to the superior quality of the POJ 2878 canes. Apparently Striped Tip was outclassed in all but the first ratoon when the Striped Tip grown at Manoa was superior to POJ 2878; in this case the POJ 2878 had produced 60 per cent tasseled stalks as compared with only 16 per cent tassel in the Tip canes.

All three varieties differed in the percentage composition of their crusher juices. In all five crops that were harvested, the Striped Tip canes had significantly higher concentrations of phosphate, while the lowest concentrations were in the H 109. In the case of potash, H 109 was also lowest in per cent K_2O for all five crops, but POJ 2878 generally had a slightly greater concentration than Striped Tip.

Although not summarized in Table IV, pH data concerned with soils at harvest do not indicate that these varieties have had any differential effect upon the soil reaction.

The Effect of Inadequate Fertilization: At both Makiki and Manoa the variety POJ 2878 only was grown on both Makiki and Manoa soil with both an adequate and an inadequate supply of fertilizer, more especially of nitrogen. The results from this comparison are summarized in Table V.

Both cane and sugar yields were greatly reduced when the crop was inadequately fertilized; this was true regardless of the soil upon which it was grown or the environment in which it developed.

The effects of "inadequate" fertilization on the per cent P_2O_5 in the crusher juice need an explanation. This is believed to be due to the fact that the available nitrogen supply was greatly deficient, and in such cases plants are generally known to take up an excessive amount of phosphate; apparently there was sufficient available phosphate in these soils even though the amount subsequently applied for the "inadequate" series was only one fourth of that given to the adequately fertilized plants.

Other than in the plant crop, the per cent K_2O found in the crusher juices of the "inadequately" fertilized group was not significantly less than that found when the canes received 4 times as much in their monthly fertilizer applications. This finding is quite contrary to our previous experiences wherein we have measured a positive relationship between potash supplied and potash found in the juice. It may be that what we have considered "adequate potash fertilization" has actually been an insufficient amount for the large amount of leafy stalks grown in pots with a restricted root area; perhaps the juice K_2O analysis itself from these five crops suggests this explanation, for the per cent K_2O in both groups quite definitely falls off with each successive harvest.

The effect of the greater supply of fertilizer (largely ammonium sulphate) on the adequately fertilized series has been to give the soil a lower pH; soil acidity in the inadequately fertilized pots has not been materially affected by the fertilization.

Fig. 1. Variety H 109 (left to right)—(1) grown on Makiki soil at Makiki; (2) grown on Makiki soil at Manoa; (3) grown on Manoa soil at Makiki; (4) grown on Manoa soil at Manoa. All with *adequate* fertilization.

Fig. 2. Variety 32–1063 (left to right)—(1) grown on Makiki soil at Makiki; (2) grown on Makiki soil at Manoa; (3) grown on Manoa soil at Makiki; (4) grown on Manoa soil at Manoa. All with *adequate* fertilization.

Fig. 3. Variety 32–8560 (left to right)—(1) grown on Makiki soil at Makiki; (2) grown on Makiki soil at Manoa; (3) grown on Manoa soil at Makiki; (4) grown on Manoa soil at Manoa. All with *adequate* fertilization.

Fig. 4. Variety 32–8560 (left to right)—(1) grown on Makiki soil at Makiki; (2) grown on Makiki soil at Manoa; (3) grown on Manoa soil at Makiki; (4) grown on Manoa soil at Manoa. All with *inadequate* fertilization.

Our Second Study*

Following the harvest of the 1940 crops from the test we have just discussed, it was decided to repeat the study on the same soils and at the same locations but to substitute two new cane varieties—32–1063 for the Striped Tip and 32–8560 for the POJ 2878—and to replant the H 109 in the same containers previously cropped to this variety. Otherwise the plan was to be identical with the previous installation, although a few additional analyses were to be included.

After harvesting, the old stubble was immediately dug out, the upper foot of soil in each container was turned up, and subsequently the roots and all but the coarser parts of the stubble were returned and thoroughly mixed into the soil; this provided a large supply of organic matter from the old cane root systems. During the next six weeks, the soils were kept moist and turned over twice to assist the decay of the organic matter. The new seed was planted on June 18, 1940. Superphosphate solution was uniformly applied under the seed pieces, and thereafter the original plan was duplicated.

The 1941 crop was harvested at the age of 386 days on July 9, 1941, and photographs of cane from a representative pot of each treatment were made a matter of record. These are shown as Figs. 1 to 4.

To assist in a correct interpretation of the results from this plant crop the data have been set up for statistical studies and an analysis to show both the main effects and their interactions. In Part A, we have a study of a $2 \times 2 \times 3$ factorial plan in which 2 climate, 2 soil, and 3 variety influences have been operative under adequate fertilization. In Part B, a $2 \times 2 \times 2$ factorial arrangement provides a study of 2 climates, 2 soils, and 2 levels of fertilization for the variety 32–8560 only.

Part A: The analysis of variance for Part A appears in Table VI; the summaries of harvest data are given in the Appendix.

TABLE VI

ANALYSIS OF VARIANCE

Part *A*—$2 \times 2 \times 3$ Factorial—*2 Climates* $\times$ *2 Soils* $\times$ *3 Varieties*
(All with adequate fertilization)

Source	D. F.	Mean squares or variances for— cane	purity	Y%C	sugar
Climate (C)	1	24,211.36†	4.84	27.7378†	366.78†
Soil (S)	1	1,487.39†	13.93	9.3636*	45.72†
Variety (V)	2	574.68†	36.56*	17.6112†	22.86†
C × S	1	920.11†	59.29*	7.8400*	32.93†
C × V	2	3.42	6.77	2.0175	4.53
S × V	2	88.68	4.94	3.1076	4.80
C × S × V	2	26.21	7.57	1.7376	1.40
Error	24	77.69	9.31	1.3304	1.74
Total	35				
Mean		48.68	85.72	10.30	5.38
C. V.		18.09%	3.56%	10.73%	24.54%

* Project A-105-No. 43.1—1941 crop.

Source	D. F.	Mean squares or variances for % N in juice	% P_2O_5 in juice	% K_2O in juice	% N in soil	pH of soil
Climate (C)	1	.000685†	.000097	.0765†	.0003	.84†
Soil (S)	1	.000667†	.014844†	.0659†	.0592†	10.56†
Variety (V)	2	.001561†	.005264†	.0178†	.0028*	.005
C × S	1	.001980†	.000392	.0011	.0064†	0
C × V	2	.000232*	.000308	.0042*	.0033*	0
S × V	2	.000062	.001360*	.0078†	.0010	.025*
C × S × V	2	.000106	.000022	.0011	.0026*	.005
Error	24	.000066	.000271	.0010	.0006	.0067
Total	35					
Mean		.030	.058	.16	.001400	5.2
C. V.		27.0%	28.37%	19.75%	17.5%	1.58%

* Favorable significance. † High significance.

Discussion of Results (Part A):

Effects of Climate: The dominating independent effect of climate upon sugar cane yields from different varieties has again been demonstrated, with Makiki producing more than three times the amount of millable cane than Manoa in a period of 12½ months. At the same time all canes grown at Makiki were superior in their quality, with the result that the Makiki sugar yields were almost four times those produced at Manoa.

An influence of climate was also found on the pH of the soil after harvest, on the percentage of potash in the crusher juices, and on the percentage of nitrogen in the juices, although this latter effect was modified by the soil upon which the cane was grown and by the cane variety. Apparently neither the phosphate content of the crusher juices, nor the available nitrogen remaining in the soil at harvest were affected by climate.

Whereas natural rainfall furnished the greater part of the irrigation water needed at Manoa, it was necessary to use considerably more and a slightly alkaline tap water at Makiki; hence this fact may account for the less acid condition in which the soils cropped at Makiki were left after harvest.

The per cent potash in the crusher juice of all three varieties was definitely higher when they were grown at Manoa. This fact verifies a similar result that we previously secured and indicates a rather significant effect from a difference in climate.

The effect of climate on the percentage of nitrogen in the crusher juices was quite definitely modified by the soil upon which the cane was grown and also by the variety. With the Makiki soil, the nitrogen content of the crusher juices was definitely higher under the conditions at Makiki than at Manoa, whereas with the Manoa soil we have no reliable proof that the climatic effects were different and, perhaps, even an indication that there was a lower percentage of N in the canes grown at Makiki on this soil. The variety 32–8560 had a definitely higher per cent N in its juice at Manoa than either 32–1063 or H 109, but at Makiki the per cent N difference between 32–8560 and 32–1063 was not significant.

Although the heavier yielding cane crops produced at Makiki on the Manoa soil had a better juice purity than the lower cane yields that were grown at Manoa,

no significant influence of climate was measured on crusher juice purity when the Makiki soil was used.

Effects of Soil: Several soil effects were found to be quite independent of interactions with either climate or variety. Thus the percentages of P_2O_5 and of K_2O in the crusher juices, as well as the pH and the available nitrogen content of the soils after harvest are believed to be real soil influences.

The Makiki soil has produced cane with considerably greater concentrations of mineral plant nutrients than the Manoa soil, and it has remained less acid in its reaction also. On the other hand the Manoa soil held a greater reserve of available nitrogen at harvest.

Other soil effects have been somewhat modified by their interactions; for instance, climatic influences have altered the soil effects on cane yields. Thus, although the Manoa soil produced more cane than the Makiki soil when cropped at Makiki, there was no proved differences in cane yield between the two soils when they were cropped at Manoa.

Cane purities and yield per cent cane were significantly better from the Manoa soil when it was cropped at Makiki, but under the Manoa environment the effect of soil on these indices of juice quality may have been even just the opposite.

As was noted for the cane yields, the sugar yields from these two soils have been differently influenced by climate, i.e., a significant increase in sugar was obtained from the Manoa soil at Makiki, but no real difference in sugar was measured between the soils when cropped at Manoa.

We also note that although the per cent N in the crusher juice of canes grown on Makiki soil at Makiki was higher than that in cane on Manoa soil at the same place, it appears that the reverse effect was quite likely secured from these same comparisons at Manoa.

Finally, it is of interest to compare the average soil acidities or pH values found in these two soils after this 1941 plant crop harvest and in the same containers following their 1940 fourth ratoons.

Soil	pH at 1940 harvest	pH at 1941 harvest
Makiki	4.8	5.7
Manoa	4.5	4.7

Since there was no evidence of an interaction between soil and climate on the pH of the soil at harvest, one may only speculate as to the real reason for this evidence of decreased soil acidity in these soils.

Effect of Varieties: Yield and quality effects from the three cane varieties were not differentially influenced by climate or soil factors. Both 32–8560 and 32–1063 produced more cane than H 109 but the difference between them was not significant; however, the superior cane quality of 32–8560 gave it a significant lead in sugar yield over 32–1063. Similarly we note a variety influence on the per cent N in the crusher juice which is apparently quite independent of other factors studied: H 109 has a much lower concentration of N than 32–1063, while 32–8560 carries a significantly greater percentage.

The variety influence on both per cent P_2O_5 and per cent K_2O in the crusher juice is apparently modified by the soil factor. For instance, 32–8560 has a much higher percentage of P_2O_5 than the other two varieties on the Makiki soil, but

not more than 32–1063 on the Manoa soil. And whereas both 32–8560 and 32–1063 have a greater concentration of K_2O in their juices than H 109 when grown on Makiki soil, there was no real per cent K_2O difference between these three varieties when they were grown on the Manoa soil.

Climate has also modified the variety effect on the per cent K_2O in the juices: 32–8560 had a higher per cent K_2O than 32–1063 when it was grown at Manoa, but at Makiki its crusher juice carried a lower concentration than 32–1063.

The per cent N in the soil at harvest showed the result of a variety x climate interaction also, i.e., H 109 left more available nitrogen in the soil at Makiki than either of the other varieties, whereas at Manoa no real differences were measured as variety effects on this soil nitrogen content.

A differential variety influence on the soil pH may also be indicated as a combined influence of the soil. On the Makiki soil, 32–8560 has apparently left a less acid condition at harvest, but on the Manoa soil this cane variety has increased the soil acidity over that planted to H 109 or 32–1063.

Part B: The analysis of variance for Part B of this study is given in Table VII; the summaries of the harvest data are given in the Appendix.

TABLE VII

ANALYSIS OF VARIANCE

Part *B*—2 × 2 × 2 Factorial—*2 Climates* × *2 Soils* × *2 Levels of Fertilization*
(Variety 32–8560)

Source	D. F.	Mean squares or variances for cane	purity	Y%C	sugar
Climate (C)	1	9,381.26†	12.18*	28.6454†	213.9648†
Soil (S)	1	654.17†	1.98	2.7473*	21.8122†
Fertilizer (F)	1	2,295.17†	101.27†	17.8538†	23.5224†
C × S	1	160.61†	43.47†	6.8054†	12.3841†
C × F	1	911.43†	.08	.3651	16.4672†
S × F	1	439.47†	13.36*	2.1243	14.9468†
C × S × F	1	133.95*	17.50*	3.1389*	9.2505†
Error	16	16.70	2.64	.5302	.4524
Total	23				
Mean		44.6	89.7	12.54	5.79
C. V.		9.16%	1.81%	5.81%	11.62%

Source	D. F.	Mean squares or variances for % N in juice	% K_2O_5 in juice	% K_2O in juice	% N in soil	pH in soil
Climate (C)	1	.000048	.000260	.0477†	.00000002	2.10†
Soil (S)	1	.000204†	.022143†	.0852†	.00000322†	5.13†
Fertilizer (F)	1	.004873†	.000532	.0155†	.00000073†	1.26†
C × S	1	.000542†	.001081*	.0035	.00000025*	.40†
C × F	1	.000141†	.000126	.0109*	.00000002	.45†
S × F	1	.000369†	.000093	.0004	.00000014	.40†
C × S × F	1	.000792†	.000220	.0014	.00000020*	.36†
Error	16	.000013	.000157	.0013	.00000004	.004
Total	23					
Mean		.026	.073	.016	.0012	5.5
C. V.		13.85%	17.12%	22.50%	16.67%	1.15%

* Favorable significance. † High significance.

Discussion of Results (Part B):

Effect of Climate: The effect of climate is again shown to be the dominant factor for 32–8560 cane and sugar yields, and also for yield per cent cane; thus Makiki again provided the more desirable climatic influences. The same differential effect of climate on juice purity was again measured; for instance, when grown on Manoa soil, the 32–8560 cane at Makiki had a significantly higher purity than duplicates grown at Manoa, but on the Makiki soil this result was not found to have been influenced by the difference in environment.

The percentages of nitrogen and of phosphate in the crusher juices were not directly influenced by the different climates, but there is evidence that climatic conditions did alter the effects upon these juice constituents which came from the differences in soils and fertilizers. For instance, although the per cent N in the juice of cane grown on Makiki soil was higher when grown at Makiki than at Manoa, this differential effect was just the reverse on the Manoa soil. Furthermore, these effects were also influenced by the fertilizer which was supplied, i.e., with adequate fertilization the foregoing statements are correct, but when an inadequate amount of fertilizer (especially nitrogen) was furnished, this interaction between climate and soil was not sufficiently effective to give any real difference in the per cent N of the juice. The per cent P_2O_5 in the juice of canes grown on Makiki soil at Manoa was higher than on this same soil at Makiki, but on the Manoa soil there was no reliable climatic effect on phosphate concentration.

There is evidence of a significant effect of climate on the per cent K_2O of the crusher juice with the cane grown at Manoa again having the higher concentration of this nutrient.

Apparently climate has played a very minor role to both soil and fertilizer in influencing the available nitrogen content of the soil at harvest. The Manoa soil has the greater per cent N at harvest regardless of climate or fertilization, and although an interaction between climate and soil is found under conditions of adequate fertilization, a similar interaction under inadequate fertilization is not identified. This will be more fully discussed under "Effect of Fertilizers."

The pH of the soil at harvest is again less acid under Makiki than under Manoa climatic influences, and this effect is apparently not changed by soil or fertilization. It may, however, be the result from using a slightly alkaline tap water (pH 7.1) for the irrigation which is necessary at Makiki.

Effect of Soil: Independent effects of soil upon the percentages of P_2O_5 and K_2O in the crusher juice, and upon the available nitrogen content and pH of soil at harvest are again indicated. The Makiki soil has produced canes with very much higher concentrations of both phosphate and potash in their juices, and at harvest was still less acid than the Manoa soil; the Manoa soil had a higher percentage of available nitrogen at harvest.

The effect of soil upon the cane yields was differentially influenced by other factors. The Manoa soil produced more cane than the Makiki soil when both soils were cropped at Makiki, but the differences were not highly significant when they were both cropped at Manoa. Furthermore, these results were obtained only when the canes were adequately fertilized, for with inadequate fertilization these cane yield differences were not proved effects of soils.

The effect of soil upon juice purity has been regulated by the difference in climate and also by the fertilization. At Makiki, the Manoa soil produced a higher purity cane than the Makiki soil when both were adequately fertilized, but with this same adequate fertilization at Manoa, the Makiki soil produced cane with the higher purity. With inadequate fertilization, however, there were no differences in purity which could be attributed to soil effects at either location.

Differential effects were also found upon the Y%C, i.e., (a) a higher recovery of sugar from cane grown on Manoa soil at Makiki under adequate fertilization, but not from Manoa soil grown at Manoa, and (b) no significant soil effects on the Y%C at either location when the fertilization was inadequate.

Sugar yields were in general higher from the Manoa soil; however, here too, we have evidence of influences by both climate and fertilization which necessitate a modification of this generalization. Thus, although the Manoa soil produced a higher sugar yield when given adequate fertilizer and cropped at Makiki than did the Makiki soil, this was the only condition where this superiority of the Manoa soil was positively established; when cropped at Manoa, with either adequate or inadequate fertilizer, the Manoa soil was not proved a better sugar producer than the Makiki soil.

And finally, the effect of soil upon the per cent N found in the crusher juice of 32–8560 was also influenced by both climate and fertilizer. Inadequately fertilized cane produced crusher juices which were apparently not influenced by either the soil or the climate where they were grown. But when cane received ample fertilizer at Makiki, the Makiki soil put a considerably higher concentration of N in the juice than the Manoa soil did, whereas an opposite effect from these two soils on per cent N in juice was found when the crop was grown at Manoa.

Effect of Fertilizer: The effects of the differences in the fertilization of this 32–8560 cane, i.e., an adequate amount vs. one fourth as much or an inadequate amount, especially of nitrogen, upon its juice purity, Y%C, per cent N in juice, and per cent N in soil at harvest are apparently not greatly changed by differences in climate or in soil. Thus a better purity, and a higher yield of recoverable sugar came from the cane which received the smaller amount of fertilizer, whereas the per cent N in the crusher juice and the per cent N left in the soil at harvest were higher from the more adequately fertilized crop.

The influence of fertilizer on the cane and sugar yields was modified by both climate and soil, especially by the former. With regard to cane, greater yields were secured from adequate fertilization at Makiki on both soils, but at Manoa, although the Manoa soil responded to the adequate fertilization, there was no reliable similar gain from the Makiki soil. Regarding sugar, we find another interesting second-order interaction, viz., adequate fertilization produced more sugar than limited fertilization when applied to Manoa soil at Makiki but on the Makiki soil this gain was not significant; furthermore, this adequate fertilization on Makiki soil was not proved more effective than inadequate fertilization when the cane was cropped either at Makiki or at Manoa.

Our differences in fertilization apparently have had no very great effect on the per cent P_2O_5 of the crusher juices. The average percentages as found (.068–.078) are considered very high and perhaps the total initial phosphate sup-

plies were so generous that subsequent differences in amounts of phosphate fertilizer applied were comparatively ineffective.

The effect of fertilizer on the per cent K_2O of the crusher juice was definitely influenced by the differences in climate. Whereas the cane grown at Makiki was not influenced, cane at Manoa which had been adequately fertilized carried a much higher per cent K_2O in its crusher juice than cane at Manoa which was less adequately supplied with fertilizer carrying potash.

The pH of the soil at harvest was influenced by the fertilizer which had been applied, but there were differences in fertilizer effects which can be traced to interactions with the effects of both climate and soil. Thus the pH of the Makiki soil when cropped at Manoa has not been significantly changed by the differences in fertilization; whereas the lower pH of this same soil at Makiki indicates an effect from the more adequate fertilization, with its large amounts of N from ammonium sulphate. The differences in acidity of the Manoa soil are quite definite effects from the fertilizations: the differences in pH is slightly larger at Makiki than at Manoa.

Summary: Once again we have quite clearly measured the dominating effects which climate exerts upon yields and composition of sugar cane. There are also definite soil effects, variety effects, and fertilizer effects, but many of these are also influenced or modified by differences in climate. Hence it is quite gratifying that we have been able to identify some of the interactions between these various factors which can affect the cane crop, and thereby secure a better understanding of both their independent and interlocking effects for guidance in growing sugar cane.

Considering the two different environments tested in these studies, it is apparent that sugar yields at Manoa can only be one third to one fourth of the yields which can be obtained at Makiki; hence we need not waste much time attempting to increase them beyond this proportion, for the climatic factors at Manoa are not favorable for greater sugar yields, even when adequate water and food are supplied, soil conditions are greatly altered, or good varieties are planted.

Some characteristic of soils other than their moisture and available nutrient content can influence sugar yields, especially when climatic influences are conducive to heavy cane yields. But when the climate limits the cane yields to low tonnages, the influence of this soil factor is not significant. It is our belief that the specific characteristic which makes one well-fertilized soil superior to another, is its better physical condition. Hence our attention to securing an improved physical condition of soils in regions where heavy cane tonnages can be grown should take precedence over similar soil improvement operations in regions where yields will be lower, for returns from the former should be considerably greater.

Speaking only for the few cane varieties which were studied, and considering only their comparative sugar yields, it would appear that the superior yielding variety was superior, regardless of the soil on which it was grown or of the climatic conditions under which it made and stored its sugar, providing it had received adequate food and water. Thus for the range in climatic conditions between Makiki and Manoa, a need for variety differentiation is not indicated if final sugar yield is the only criterion for preference. (Unfortunately, data to

estimate profits from these sugar yields are not available, and it is not unlikely that the costs of production will be quite different.)

Of all four factors studied, the effect on sugar yields which comes from fertilizer is the most completely tied up with complementary effects from soil and climate. Apparently there is little to be gained from increased fertilization under low sunlight conditions such as are found at Manoa, *i.e.*, piling on the fertilizer will not give increases in sugar under such climatic influences. Similarly, increasing the fertilizer for a soil with an inferior physical condition has little effect upon the sugar yields, whereas a similar increase on a soil with superior physical characteristics does pay handsomely in larger crops of sugar.

The influence of any one of these four factors upon the percentage composition of the crusher juices is in some cases independent of, and in other instances dependent on some other factor. (This may be a reason why we have found it difficult to interpret many crusher juice analyses.) For instance: although the effect from different soils upon the per cent P_2O_5 and per cent K_2O of crusher juices is apparently independent of other factors, this is not the case upon the per cent N, for both a difference in climate and in fertilizer have modified the effect of soil upon the nitrogen concentration. Similarly, although a variety influence upon the per cent N in crusher juices is found to be independent of soil or climate, this same direct influence on the per cent K_2O in juice was not found when the varieties were grown on different soils or under different environments. And although a difference in fertilizer resulted in a corresponding difference in the per cent N of crusher juices, regardless of soil or climate, the fertilizer's effect on per cent K_2O was not the same when used under different climatic conditions.

Soil effects on the nitrogen content and pH of soil at harvest were quite definite and not influenced by other factors. Climate had an independent effect upon the pH; also a direct effect from the difference in fertilization was measured on the per cent N in soil at harvest. However, the variety effects on these two soil measurements were not always the same: (a) under different climates, variety effects on per cent N were influenced by differences in climate; and (b) on different soils the variety effects on soil pH were somewhat modified.

The complexity of effects produced on sugar cane by only these four factors—climate, soil, variety, and fertilizer, both separately and by their interactions—is apparent from the results that have been measured and recorded. Undoubtedly the picture is still more complex when other growth factors are involved. All of this sums up to the fact that attempts to allocate many of the possible cause and effect relationships to specific growth factors may be quite unsatisfactory, because of the many other non-identified conditions which can be involved when sugar cane is grown in the field.

Appendix

Part A—Summary of Harvest Data

Main Effects

1. *Effects of Climate* (Average of 18 Replicates)

Measurement	Crop grown at Makiki	Crop grown at Manoa	Minimum difference required for significance
Cane (lbs.)	74.6	22.8	6.1
Purity	86.1	85.4	ns
Y%C	11.18	9.42	.79
Sugar (lbs.)	8.57	2.19	.91
% N in crusher juice	.034	.025	.006
% P_2O_5 in crusher juice	.056	.060	ns
% K_2O in crusher juice	.11	.20	.02
% N* in soil at harvest	.0015	.0014	ns
pH of soil at harvest	5.4	5.0	.06

2. *Effects of Soils* (Average of 18 Replicates)

Measurement	On Makiki soil	On Manoa soil	Minimum difference required for significance
Cane (lbs.)	42.3	55.1	6.1
Purity	85.1	86.3	ns
Y%C	9.79	10.81	.79
Sugar (lbs.)	4.25	6.51	.91
% N in crusher juice	.034	.026	.006
% P_2O_5 in crusher juice	.078	.038	.011
% K_2O in crusher juice	.20	.12	.02
% N* in soil at harvest	.0011	.0019	.0002
pH of soil at harvest	5.7	4.7	.06

3. *Effects of Varieties* (Average of 12 Replicates)

Measurement	H 109	32–8560	32–1063	Minimum difference required for significance
Cane (lbs.)	41.0	54.4	50.7	7.4
Purity	84.3	87.7	85.2	2.6
Y%C	9.40	11.68	9.83	.95
Sugar (lbs.)	4.02	6.78	5.34	1.11
% N in crusher juice	.018	.040	.032	.007
% P_2O_5 in crusher juice	.036	.078	.061	.014
% K_2O in crusher juice	.11	.18	.18	.03
% N* in soil at harvest	.0016	.0013	.0014	.0002
pH of soil at harvest	5.2	5.2	5.2	ns

* Water soluble N only. ns = not significant.

Significant Interactions

4. *Between Climate and Soils* (Average of 9 Replicates)

Measurement	Climate	On Makiki soil	On Manoa soil	Minimum difference required for significance
Cane (lbs.)	At Makiki	63.1	86.1	
	At Manoa	21.4	24.1	8.6
Purity	At Makiki	84.2	88.0	
	At Manoa	86.0	84.7	3.0
Y%C	At Makiki	10.20	12.16	
	At Manoa	9.38	9.47	1.12
Sugar (lbs.)	At Makiki	6.49	10.65	
	At Manoa	2.02	2.36	1.28
% N in juice	At Makiki	.046	.022	
	At Manoa	.022	.029	.008
% N in soil	At Makiki	.0010	.0020	
	At Manoa	.0012	.0017	.0003

5. *Between Climate and Varieties* (Average of 6 Replicates)

Measurement	Climate	Variety H 109	Variety 32–8560	Variety 32–1063	Minimum difference required for significance
% N in juice	At Makiki	.018	.044	.041	
	At Manoa	.017	.036	.023	.010
% K_2O in juice	At Makiki	.07	.12	.15	
	At Manoa	.16	.25	.21	.04
% N in soil	At Makiki	.0018	.0013	.0013	
	At Manoa	.0014	.0014	.0016	.0003

6. *Between Soils and Varieties* (Average of 6 Replicates)

Measurement	Soil	Variety H 109	Variety 32–8560	Variety 32–1063	Minimum difference required for significance
% P_2O_5 in juice	Makiki	.052	.110	.073	
	Manoa	.020	.045	.048	.020
% K_2O in juice	Makiki	.13	.24	.24	
	Manoa	.10	.12	.12	.04
pH of soil	Makiki	5.7	5.8	5.7	
	Manoa	4.7	4.6	4.7	.10

Part B—Summary of Harvest Data

Main Effects

1. *Effects of Climate* (Average of 12 Replicates)

Measurement	Crop grown at Makiki	Crop grown at Manoa	Minimum difference required for significance
Cane (lbs.)	64.4	24.8	3.5
Purity	90.4	89.0	1.4
Y%C	13.63	11.45	.63
Sugar (lbs.)	8.77	2.80	.58
% N in juice	.027	.024	ns
% P_2O_5 in juice	.070	.076	ns
% K_2O in juice	.11	.20	.03
% N in soil at harvest	.0011	.0012	ns
pH of soil at harvest	5.8	5.2	.06

2. *Effects of Soils* (Average of 12 Replicates)

Measurement	On Makiki soil	On Manoa soil	Minimum difference required for significance
Cane (lbs.)	39.4	49.8	3.5
Purity	89.4	90.0	ns
Y%C	12.20	12.88	.63
Sugar (lbs.)	4.83	6.74	.58
% N in juice	.029	.023	.003
% P_2O_5 in juice	.103	.043	.011
% K_2O in juice	.22	.10	.03
% N in soil at harvest	.0008	.0015	.0002
pH of soil at harvest	5.9	5.0	.06

3. *Effect of Fertilizer* (Average of 12 Replicates)

Measurement	With adequate fertilizer	With inadequate fertilizer	Minimum difference required for significance
Cane (lbs.)	54.4	34.8	3.5
Purity	87.7	91.8	1.4
Y%C	11.68	13.40	.63
Sugar (lbs.)	6.78	4.80	.58
% N in juice	.040	.012	.003
% P_2O_5 in juice	.078	.068	ns
% K_2O in juice	.18	.13	.03
% N in soil at harvest	.0013	.0010	.0002
pH of soil at harvest	5.2	5.7	.06

Significant First-Order Interactions

4. *Between Climate and Soils* (Average of 6 Replicates)

Measurement	Climate	On Makiki soil	On Manoa soil	Minimum difference required for significance
Cane (lbs.)	At Makiki	56.6	72.2	
	At Manoa	22.2	27.5	5.0
Purity	At Makiki	88.8	92.1	
	At Manoa	90.1	88.0	2.0
Y%C	At Makiki	12.76	14.50	
	At Manoa	11.64	11.25	.87
Sugar (lbs.)	At Makiki	7.10	10.44	
	At Manoa	2.57	3.04	.82
% N in juice	At Makiki	.035	.020	
	At Manoa	.025	.026	.004
% P_2O_5 in juice	At Makiki	.093	.046	
	At Manoa	.113	.039	.015
% N in soil	At Makiki	.0007	.0016	
	At Manoa	.0009	.0015	.0003
pH of soil	At Makiki	6.1	5.4	
	At Manoa	5.8	4.6	.08

5. *Between Climate and Fertilizer* (Average of 6 Replicates)

Measurement	Climate	With adequate fertilizer	With inadequate fertilizer	Minimum difference required for significance
Cane (lbs.)	At Makiki	80.3	48.0	
	At Manoa	28.4	21.2	5.0
Sugar (lbs.)	At Makiki	10.59	6.96	
	At Manoa	2.96	2.64	.82
% N in juice	At Makiki	.044	.011	
	At Manoa	.036	.013	.004
% K_2O in juice	At Makiki	.12	.11	
	At Manoa	.25	.15	.04
pH of soil	At Makiki	5.4	6.1	
	At Manoa	5.1	5.2	.08

6. *Between Soil and Fertilizer* (Average of 6 Replicates)

Measurement	Soil	With adequate fertilizer	With inadequate fertilizer	Minimum difference required for significance
Cane (lbs.)	Makiki	44.9	33.9	
	Manoa	63.9	35.8	5.0
Purity	Makiki	86.6	92.2	
	Manoa	88.7	91.3	2.00
Sugar (lbs.)	Makiki	5.04	4.63	
	Manoa	8.52	4.96	.82
% N in juice	Makiki	.047	.011	
	Manoa	.033	.013	.004
pH of soil	Makiki	5.8	6.0	
	Manoa	4.6	5.4	.08

Significant Second-Order Interactions

7. Between Climate and Soil and Fertilizer (Average of 3 Replicates)

Measurement	Climate	With adequate fertilizer: On Makiki soil	With adequate fertilizer: On Manoa soil	With inadequate fertilizer: On Makiki soil	With inadequate fertilizer: On Manoa soil	Minimum difference required for significance
Cane (lbs.)	At Makiki	65.9	94.8	47.3	49.6	
	At Manoa	23.9	33.0	20.5	21.9	7.1
Purity	At Makiki	85.2	91.7	92.4	92.5	
	At Manoa	88.1	85.7	92.1	90.2	2.8
Y%C	At Makiki	11.36	14.42	14.16	14.58	
	At Manoa	10.72	10.20	12.56	12.30	1.27
Sugar (lbs.)	At Makiki	7.51	13.67	6.69	7.22	
	At Manoa	2.56	3.37	2.57	2.71	1.16
% N in juice	At Makiki	.061	.027	.009	.013	
	At Manoa	.033	.040	.013	.013	.006
% N in soil	At Makiki	.0007	.0020	.0006	.0012	
	At Manoa	.0011	.0016	.0008	.0013	.0004
pH of soil	At Makiki	6.0	4.8	6.2	6.0	
	At Manoa	5.7	4.5	5.8	4.7	.11

Soil and Plant Material Analyses by Rapid Chemical Methods—III

By Francis E. Hance

CONTENTS

Foreword

Following the development of R.C.M. (Rapid Chemical Methods of Analysis) at this Experiment Station in 1932 (1), a normal expansion of the general scheme has occurred (2) and widespread adoption of this or similarly and independently developed methods have taken place in various agricultural regions throughout the world.

R.C.M. apparently has served a useful purpose and will continue to develop and expand. However, it is not endowed with infallibility nor can it boast of freedom from certain inherent limitations which, fortunately in most cases, may be subject to correction or practical modification without sacrifice of its essential characteristics of simplicity and rapidity of analytical accomplishment.

The present discussion presents detailed suggestions along lines of refinement and modification of R.C.M. on the basis of ten years of experience, both by ourselves and by workers in other countries with whom we have maintained contact in person or by correspondence.

New methods of analyses will be described. Particular attention will be given to the elucidation of obscure details in the earlier papers which have shown a need for clarification.

> The Clarification of Points Which Have Been Found to Cause a Certain Amount of Confusion in the Original Publication ("Soil and Plant Material Analyses by Rapid Chemical Methods"—The Hawaiian Planters' Record, 40: 189–299, 1936, and Agricultural and Chemical Series Bulletin No. 50).

Reagent No. 1, K_2O:

On page 236: 500 grams of C.P. sodium acetate should be corrected to read 5000 grams.

The Potash Determination:

The Potash Rotator (pages 203–207): No changes have been found necessary or desirable in the construction or operation of this instrument. Of the several hundred which have been manufactured in Honolulu and put in service during the past ten years, none has broken down, to the best of our knowledge, but about five instruments have been worn out by extensive and hard usage.

Maximum wear on the rotator occurs along the point of contact between the brass spindle and the wooden rotor. As originally designed, the provision of a

metal bushing for the rotor was discarded because it was felt that lubrication would be neglected by some users and as a consequence the instrument would soon develop a rasp-like squeak. As a substitute the hardwood rotor was impregnated with grease along its centrally located shaft opening. Long usage enlarges this opening and wobbling develops. The condition is not serious and may be corrected by replacing the old rotor with a turned replica. The rubber tire on the rotor consists of nothing more than a very wide rubber band. A long sleeve or tube of thin rubber having about the following specifications may be purchased from chemical supply houses: Gooch rubber tubing, 1½" diameter. Sections may be cut from the sleeve as required and placed on the rotor.

Note: Always remove the rotor from the spindle before attempting to apply the rubber tire. Unless this precaution is observed the spindle may be bent out of line and thus rendered considerably less effective.

The upper cover of the rotator should be removed about once or twice a year and the motor, bearings and governor assembly should be oiled with a good quality thin oil. Calibration of the speed of the rotator is important, but when proper adjustment is once made its maintenance is a minor problem because the rotator operates on 60-cycle alternating current through an induction motor. However, it is desirable to check speed of rotation at the time of oiling and, if necessary, to adjust the arm of the braking mechanism to bring the movement to exactly 78 r.p.m.

The Potash Vials: Short-form shell vials are specified in Bulletin 50. We have found it necessary to discard vials which have become scratched by repeated washings. They may be purchased at small cost from supply dealers. These vials should measure about 17.5 mm. outside diameter, 15.5 mm. inside diameter and 60 mm. in length. When a supply of vials is received, it will likely develop that the inside diameters vary to such an extent that the height of a measured 1 ml. of liquid in a series may be lengthened or shortened sufficiently from tube to tube to throw off the accuracy of comparable turbidimetric readings when using the vials by random selection. Accordingly, it has been found advantageous to prepare a turned wooden cylinder just large enough in diameter to fit snugly into a vial of correct inside diameter. (A 9/16" wood dowel may do.) Using the prepared cylinder as a gauge, several gross of the vials may be tested and those found larger or smaller than the gauge may be reboxed and returned to the dealer for credit or exchange. As a rule the dealer will not object to accepting the odd vials because the variability in diameter is of little consequence to the average user. To register a carton of your own rejects on your dealer's shelves it is a good idea to place a small circle with a cross in it on the bottom of each carton you return. On future orders specify new goods, or explain the significance of your reject markings.

The True Values of R.C.M. Potash Findings for Soils and Crusher Juice:

R.C.M. Potash in Soil: By referring to Bulletin 50 one may observe that the soil potash procedure was perfected through a series of experimental trials, adjustments and refinements. Furthermore, it was essential to develop the method in such a manner that the transition from "kit" determination to the more precise R.C.M. could take place without sacrificing or adjusting the quite extensive com-

pilation of "kit" figures which were already on file. Still further it should be realized that two of the important objectives sought in the new procedure were to devise mechanical aides which would standardize the shaking operation in the analysis and provide a means of determining the extent of turbidity produced in the test (a direct index of potash content) under uniform conditions of illumination and arrangement of equipment. All these modifications were required to be calibrated in terms which would be directly comparable and equivalent to current data produced with identical soil specimens by an expert "kit" analyst.

Consequently, R.C.M. soil potash data were deliberately (but unfortunately) made to match as closely as we possibly could the general run of values turned out by a first-class kit operator on any given series of soil specimens. Later, research studies on the R.C.M. procedure revealed the fact that, on the average, R.C.M. soil potash figures, as given in the tables accompanying the method, represent the true percentages of potash extracted from the soil *times* the factor 0.4. Thus, standard R.C.M. values are two fifths of the actual concentration of K_2O extracted from the soil.

R.C.M. Potash in Crusher Juice or Plant Sap: The development of this procedure was made to meet a specified need. There was no necessity for introducing modifications to make the method level off to the values of another. Therefore the table accompanying this method is based on the actual amounts of potash which are present in the specimen.

A Factor For Conversion of R.C.M. Soil Potash Figures to Approximately Comparable Replaceable Potash Values:

Multiply the R.C.M. percentage value as shown in the R.C.M. table by 3.3. This factor was determined entirely by empirical means and represents an average of several thousand analytical comparisons. No established reliability is claimed for it.

The Preparation of R.C.M. Reagents

The exact composition of all reagents used in R.C.M. work is published in the bulletins (1, 2) devoted to the subject. At the very beginning of the adoption of R.C.M. by Hawaiian plantations it was recommended that all plantations obtain their reagents from a central source to insure uniformity of these products and thus avoid irregularities in quality and condition of reagents. It was pointed out that unless general adherence to this plan was observed it would prove practically impossible to conduct accurate checking determinations at the Experiment Station of duplicate soil or plant specimens which various plantation analysts had previously analyzed and which had been forwarded to Honolulu (as is the present rule at periodic intervals) in order to check the reliability of plantation analyses from time to time.

While it is true that the exact chemical composition of all reagents is recorded in the bulletins, it is also true that their preparation involves experience, the purchase of large quantities of chemicals which have to be reanalyzed before use and a knowledge of chemistry. Some reagents are prepared in large volume and stored for 6 months or longer for secondary reactions to subside before they can be

properly standardized and checked preparatory to packaging for Experiment Station or plantation use. Other reagents deteriorate upon standing and must be prepared in small lots and at frequent intervals. Still others are affected by alkali in glass containers and must be packaged in bottles which have been coated on the inner surfaces with a thin but substantial lining of flexible and inert wax. These and other considerations make it imperative that responsibility for the manufacture and distribution of all reagents used by all groups of R.C.M. workers in a given confine be centralized in one laboratory.

Deviation from this practice has invariably led to disaster in the few cases which have occurred in Hawaii. Two of these will be cited briefly because of the far-reaching effects which were produced in temporary but serious disruptions of the personnel and organization of two large plantations.

A plantation manager wrote to the Experiment Station stating that although he had established an R.C.M. laboratory and staff of analysts he had found that the system could not be used with the soils of his locality. To support his claim he described a test of the system which had been made that day in which a certain field soil failed to show even a trace of phosphate by R.C.M. and yet field experiment and Mitscherlich studies had indicated that the phosphate reserves in this soil were so high that additional phosphate nutrient was not required. To clinch his case he described another test in which a soluble phosphate fertilizer was added to the soil in question immediately before analysis by R.C.M. The analysis revealed even in this instance no trace of phosphate. He requested authorization to return all equipment and reagents to the Experiment Station and stated that the laboratory would have to be discontinued.

A visit was made by one of us to this plantation by overnight steamer. The investigation which followed disclosed that a laboratory analyst—from the best of motives—offered to purchase the necessary chemicals from a local drug store and prepare the reagents as they were needed, using the R.C.M. bulletins and notes he had compiled during his period of training at the Experiment Station. His offer was accepted by the agriculturist. As may be expected, this man ran afoul of the complications involved in processing ammonium molybdate for Reagent No. 4. Also, his stannous chloride solution had completely oxidized, was not stored over metallic tin and had the appearance of skim milk in his service dropping bottle. The chemicals he purchased were also at fault in that they were not of reagent quality. Hence, due to the combined effects of the circumstances cited, R.C.M. analyses broke down completely in this laboratory. The manager did not appear to know that one of his analysts was preparing reagents.

In anticipation of the likely trouble, small quantities of the two properly prepared reagents mentioned above were taken to the plantation at the time of the visit. A demonstration by the visiting chemist to the manager, agriculturist and laboratory staff—using the properly prepared reagents—soon clarified the situation. Immediately thereafter the homemade reagents were thrown away, new supplies were ordered from the Experiment Station and in a few days the laboratory was reestablished. It is functioning today (6 years later) without apparent difficulties.

The other case involved Experiment Station reagents as used in the soil potash determination. Another plantation manager wrote to the Experiment Station and took us to task for supplying reagents which he and his staff had been convinced

were worthless. He stated that he could not afford to abandon his R.C.M. soil survey and since we apparently were not preparing high-grade reagents he was about to arrange with a mainland manufacturer to supply first-class materials. Proof of his claim was submitted in comparison test data in which Experiment Station reagents were used separately as compared with similar reagents obtained at appreciable expense and trouble by fast express from a laboratory in the middle west. The data clearly showed our reagents to be absolutely useless. They were. There was no doubt of it. An immediate investigation by one of us brought out the fact that as a prank a plantation worker in the mill laboratory removed about 75 per cent of Reagent No. 3 from the stock container in the R.C.M. laboratory and substituted water in its place. This reagent is used to precipitate potash for a turbidity reading after agitation on the rotator. It must contain at least 80 per cent of absolute alcohol to accomplish the desired purpose. In addition to this difficulty, Reagent No. 2, a cobaltous and very unstable compound, had been purchased from the Experiment Station in an entirely too large amount a year or more previously and through exposure to sunlight and by returning daily unused portions of the reagent to the stock container each evening the entire lot had thoroughly decomposed. Adjustments were made to the satisfaction of the management and staff and this laboratory is successfully operating today using, exclusively, Experiment Station service facilities and reagents.

These and a few similar experiences have made it possible to compensate for difficulties of this character and to establish a system of reagent and equipment control which is quite effective in its reliability and uniformity. However, emphasis is still stressed on the obviously essential "unit source of supply." The cost of reagents to plantation and other users is based upon the cost of chemicals plus the expenses incurred in preparing, bottling, packing and shipping them. All other services on R.C.M. matters tendered by the Experiment Station to plantations and associate users are not subject to a direct charge.

The Plantation-Experiment Station Checking System

This system was described fully in Bulletin 50. Briefly stated, it operates as follows: The plantation agriculturist (not the analyst) will place aside about a 1-pound representative portion of, say, every fiftieth soil specimen which has previously been collected and prepared for analysis, and a sufficient quantity of occasional plant material from every series of samples which are undergoing analysis in the plantation laboratory. At from a 2-week to 1-month interval these reserved samples are sent by parcel post to the Experiment Station with a copy of the corresponding analytical data reported by the R.C.M. analysts on these analyzed materials. The plantation R.C.M. staff is acquainted with the fact that a certain number of their analyses are to be repeated by the Experiment Station on the residues of specimens which they have previously worked. They do *not* know how many or which samples are to be checked.

Upon arrival at the Experiment Station the samples are assigned to any one of several Experiment Station analysts for repeat determinations. When the analyses are completed the results are compared with the plantation figures and, if necessary, assigned to a second or even a third Experiment Station analyst for recheck or verification. A report is then rendered the plantation manager, show-

ing comparison data (his and ours). Comments and suggestions are made on the comparison figures and recommendations are included, when appropriate, which are designed to assist the plantation analyst in correcting his technic, testing his reagents or in making a more exacting repeat analysis for his own satisfaction.

A typical example is given below of original data and Experiment Station comparison figures as determined soon after it was learned that a plantation R.C.M. staff had been finding it increasingly difficult to obtain concurring results in their soil potash work.

An Experiment Station analyst was assigned to cooperate with the plantation men in locating and correcting the difficulty. A set of comparison figures follows

"X" AGRICULTURAL COMPANY, LIMITED

Soil Analyses

	Phosphate, P_2O_5						Potash, K_2O					
	%		Lbs./a-ft.		Group		%		Lbs./a-ft.		Group	
Soil No.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.
14388, 2A1	+.032	+.032	+800	+800	High	High	.018	.010	450	250	High	Med.
14389, 4	+.032	+.032	+800	+800	High	High	.004	.003	100	75	Low	Low
14390, 1B	+.032	.010	+800	250	High	Dbt.	.014	.006	350	150	High	Dbt.
14391, 2	+.032	+.032	+800	+800	High	High	.010	.009	250	225	Med.	Med.
14392, 3	.0034	.0015	85	38	Med.	Med.	.012	.012	300	300	Med.	Med.
14393, 4	.010	.0015	250	38	High	Med.	.009	.010	225	250	Med.	Med.
14394, 14A	.006	.005	150	125	High	High	.011	.014	275	350	Med.	High
14395, 3	.004	.0028	100	70	High	Med.	.005	.007	125	175	Dbt.	Dbt.
14396, 9	.007	.007	175	175	High	High	.012	.009	300	225	Med.	Med.
14397, 4	.0006	.0002	15	5	Low	Low	.011	.009	275	225	Med.	Med.

Note: Plus sign denotes quantity greater than that indicated.

disclosing the potash irregularity. The entire comparison data of P_2O_5 and K_2O are included. Note the time interval, please, for reference to a succeeding and similar check.

In due course the difficulty was located at the plantation, explained fully to the staff and the work was reorganized without incurring ill feeling of any kind. Several weeks went by before another Station check was made. In the meantime the plantation staff reported that their former soil potash difficulties had ceased. Later, an extensive checking comparison was again made. The data follow:

"X" AGRICULTURAL COMPANY, LIMITED

Soil Analyses

	Phosphate, P_2O_5						Potash, K_2O					
	%		Lbs./a-ft.		Group		%		Lbs./a-ft.		Group	
Soil No.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.	HSPA	Pltn.
202....	.006	.006	150	150	High	High	.003	.003	75	75	Low	Low
204....	.006	.006	150	150	High	High	.005	.004	125	100	Low	Low
205....	.0015	.0010	38	25	Med.	Dbt.	.004	.003	100	75	Low	Low
207....	.0028	.0020	70	53	Med.	Med.	−.003	.003	− 75	75	Low	Low
209....	.004	.004	100	100	High	High	−.003	.003	− 75	75	Low	Low
210....	.0028	.0028	70	70	Med.	Med.	−.003	.003	− 75	75	Low	Low
212....	.015	.015	375	375	High	High	.014	.014	350	350	High	High
229....+	.032	.032	+800	800	High	High	.025	.025	625	625	High	High
231....	.004	.004	100	100	High	High	.004	.003	100	75	Low	Low
233....	.0021	.0028	53	70	Med.	Med.	−.003	.003	− 75	75	Low	Low
234....	.0012	.0011	30	27	Dbt.	Dbt.	.004	.003	100	75	Low	Low
235....	.0012	.0012	30	30	Dbt.	Dbt.	.004	.003	100	75	Low	Low
237....	.0015	.0012	38	30	Med.	Dbt.	.005	.003	125	75	Dbt.	Low
238....	.0028	.0021	70	53	Med.	Med.	.006	.005	150	125	Dbt.	Dbt.
241....	.004	.0034	100	85	High	Med.	.004	.004	100	100	Low	Low
242....	.0028	.0021	70	53	Med.	Med.	−.003	.003	− 75	75	Low	Low
245....	.0028	.0028	70	70	Med.	Med.	.004	.004	100	100	Low	Low
246....	.0012	.0012	30	30	Dbt.	Dbt.	.0055	.005	138	125	Dbt.	Dbt.
248....	.0012	.0012	30	30	Dbt.	Dbt.	.004	.003	100	75	Low	Low
250....	.0034	.0034	85	85	Med.	Med.	.006	.006	150	150	Dbt.	Dbt.

Note: Plus sign denotes quantity greater than that indicated.
Minus sign denotes quantity less than that indicated.

The improvement, it may be observed, is substantial and real. Rigorously pursuing a checking system appears to justify the effort.

Training Experiment Station and Plantation Workers, University Students and Others in R.C.M.

As its designation implies, R.C.M. determinations must be rapidly performed. Of greater import, however, they must be accurate, subject to analytical check and not require elaborate equipment. Simplicity of performance makes them adaptable to use by those previously untrained in chemistry. However, it has been found by our own experiences that a short course of organized instruction in R.C.M. actually fits the student for quite a satisfactory performance in this work, regardless of his previous training. It has also been found that instruction in the general theory of chemical analysis, although not essential, is a decided help in enabling the analyst to grasp the significance of the determination as well as perform the required analytical steps with a greater degree of assurance and understanding. The course of instruction, therefore, embraces a training in performing successive steps in the various analyses and includes an explanation of the chemistry of the analysis and the reasons which govern the progressive movement of the determination to its analytical conclusion.

The time devoted to the course varies between 10 days and 4 weeks, depending entirely on the aptitude of the student and upon the number of determinations required to complete his curriculum.

Instruction is given by department chemists, all graduates, who have contributed to the development of R.C.M. and who are engaged in identical studies in the Experiment Station laboratories.

Those taking the courses are principally plantation young men having high school or more extended education. They are sent to Honolulu at the expense of the plantation, returning for duty after showing proficiency in a standard graded series of performance examinations given the candidate at the conclusion of his course of instruction. Others taking the course include all students-in-training of the Agricultural department, this Experiment Station; a number of students taking work at the University of Hawaii; and occasionally a visiting agricultural scientist from the mainland or from another country.

Modifications of Existing R.C.M. Procedures

Phosphate:

A simple, but greatly improved procedure which should be used in the analysis of soils which are well supplied with phosphate is as follows: In the present procedure the extracted and purified phosphate residue is dissolved in 10 ml. of Reagent 4, P_2O_5. A portion of this solution is added to a phosphate vial (a vial which also should be calibrated to a standard internal diameter), filling the tube to within a quarter inch of the top. Stannous chloride reagent is added to develop the color. However, if the color developed is darker than the deepest hued color standard, then the analyst transfers half of his test solution to a clean, dry vial and adds an equal volume of Reagent 4, P_2O_5. Thereupon the color is brought to full intensity again by adding additional stannous chloride reagent.

Due to the fugitive nature of the developed color reimposed upon a similarly treated test specimen, L. Kawamura and E. Watanabe have found by long experience that a modification of this procedure gives much more reliable and satisfactory results.

The modification consists in separating 10 ml. of the solution of the purified phosphate residue into two vials, the *first* containing about 3½ ml. and the *second* the remainder (approximately 6½ ml.) of the solution. Now, develop the color as usual in the second vial. If the blue color produced is too intense, add 3½ ml. of Reagent 4, P_2O_5 to the reserved 3½ ml. of dissolved phosphate and proceed as usual, using a factor of 2 in recording the result to compensate for the dilution.

The correct dimensions of standard phosphate vials should approximate 12½± mm. outside diameter, 11± mm. inside diameter, by 102 mm. length.

Total Nitrogen:

A suggestion follows regarding the determination of total nitrogen by R.C.M. Near the close of the procedure, when distilling off the ammoniacal fraction from the reaction chamber, standard practice has continued the distillation until the volume of the distillate reached a predetermined level marked by an etched ring on the receiver. Later, when the distillate cools to room temperature and the volume of the distillate, as a consequence, has shrunk below the marked level, distilled water is added to make up the loss in volume.

It has been found in practice that better results may be secured, with fewer manipulations, and that greater assurances may be had that all of the ammonia has been distilled over if the distillation is continued until the level of the distillate reaches a point about one-eighth inch above the mark on the receiver. By following this practice, it will be found that upon cooling, the volume of distillate, as a rule, stands at the prescribed level and, therefore, it will not have to be tampered with prior to concluding the determination.

Available Nitrate Nitrogen:

Difficulties have been encountered in this determination in securing a sufficiently rapid reaction of Reagent 7, N with the residue obtained upon evaporation of the 25-ml. filtrate. It is suggested, therefore, that after the residue from the filtrate has been obtained by evaporation the crust formed be loosened and broken up with a glass rod before the addition of Reagent 7, N. If this simple modification is adopted we believe it will result in a more rapid and a more satisfactory determination.

A Refinement in the R.C.M. Determination of Phosphate in Soil:

This modification in analytical procedure, when substituted for that now in use, does not detract from correlation values already considered or from those to be determined. The refinement is a development resulting from research which has been in progress for some time on all R.C.M. procedures and which will continue in the future. The magnitude of correction in soil phosphate values with most soils, of course, will be found insignificant. In such cases the modification may be disregarded. However, the simplicity of the revised procedure renders the checking of the point a very easy and inexpensive matter. Interference with the estimation of phosphate in soil as occasioned by the presence of calcium, silicates,

nitrates, carbonates, ferrous iron, or traces of selenium, arsenic, titanium, aluminum, or manganese are eliminated in this simple analytical revision.

A number of common or of rarer soil constituents, which may or may not be present in any given soil, react in the phosphate determination in a manner which fictitiously increases the final reading to a variable degree. To insure greater accuracy, it is recommended that the following modification of the R.C.M. determination of phosphate in soil, (a development by T. Nishimura, Assistant Chemist), be used in all laboratories, *provided* the modified procedure shows consistently a *lower,* though but slightly smaller concentration of the nutrient than the result obtained on the same soil with the existing method.

Modified Procedure: Treat the soil by the regular procedure for the rapid estimation of phosphate in soils up to and including the close of operations in Step No. 10. Then:

1. To the concentrated hydrochloric acid-treated residue, add 20 drops of Reagent 11, P_2O_5 from a dropping bottle.
2. Evaporate to dryness as usual on an electric hot plate.
3. Add 20 drops of concentrated hydrochloric acid and evaporate again.
4. Now, add 10 drops of concentrated nitric acid and evaporate to dryness.
5. Add 10 drops of concentrated hydrochloric acid and again evaporate to dryness. Repeat the addition of concentrated hydrochloric acid and evaporate to dryness once more.
6. Proceed with Step No. 11 of the regular procedure as usual and continue with the rapid estimation of phosphate in soil.

Interfering substances are volatilized or rendered impotent by the modified treatment. Reagent 11, P_2O_5 consists of a mixture of hydrobromic and hydrochloric acids. The appearance of a reddish coloration in the residue after the bromine treatment may be expected. It will be dissipated, however, by the subsequent nitric acid digestion.

Note: Reagent 11, P_2O_5 is prepared by mixing 25 ml. of hydrobromic acid (48%, sp.gr. 1.5) and 75 ml. hydrochloric acid (sp.gr. 1.18 - 1.19). Store the solution in an amber-colored, glass-stoppered bottle.

Leaf-Punch Nitrogen:

Procedure:

1. Obtain samples in the field from growing cane.
2. The procedure is based on sampling a definite grouping of leaves of the plant but with random selection of stalks. In general, the object consists in obtaining a representative sample of cane growing in a field. In a stand of cane there may exist different orders of stalks, including tasseled and untasseled canes. Experience thus far has indicated that for consistency of results only the untasseled cane should be sampled. In selecting stalks for sampling, as much of the primary growth is included as may be consistent with the principle of random selection.

To insure reliability of results two composite samples are obtained from each field. Two sampling stations are thus established per field, each station comprising an area of about 25 feet square (25′x25′). Sixty leaf-punch disks constitute a sample. Two disks are taken from each leaf in a region located about halfway along the blade and about one half the distance between the midrib and the outer

edge of the leaf. The two disks may be spaced about an inch apart along the blade. The critical sampling zone comprises that portion of the leaf system represented by the 4th, 5th and 6th leaves, counting from the top of the plant, according to the Clements-Martin system of nomenclature. In this system the spear-like spindle, if definitely visible, is counted as the first leaf, the adjacent leaf enfolding this spindle as the second leaf, and the numbering then proceeds consecutively downward along the stalk. Sometimes this spear-like spindle is not definitely visible, but in its place is found a leaf just beginning to unfurl; this, then is counted as the first leaf. These three designated leaves (4th, 5th and 6th) appear to comprise that portion of the plant which will yield reliable information concerning the "nitrogen index." (The nitrogen content percentage of the specimen has been termed the "nitrogen index" by H. P. Agee.)

Sampling may start with cane about three months of age. For young cane, not yet head high (less than 6 feet from base to top of foliage), only the 4th leaf is punched. As the plant grows, the 5th and 6th leaves are included. The full complement of 4th, 5th and 6th leaves may be sampled usually after the cane has reached or exceeded the above designated height. When the full complement of leaves comprises the material to be sampled, ten stalks are selected for the purpose in each station. For young cane, a sufficient number of stalks are selected to insure a 60-disk sample.

3. Where it is desired to obtain leaf specimens before the plant reaches an age of three months, cane growing not longer than a period of two months may be sampled. In such a case only the third leaf should be punched and this obvious deviation from the regular sampling order should be recorded with the analytical data accruing from the analysis.

4. Transfer disks to a small tin box and cover securely.

5. Remove cover and dry in electric oven at 100° C. for 3 hours, or at 80° C. for 5 hours (or overnight). (Cover and receptacle may be nested.) When dry, remove cans from oven; replace covers. Place cans in a desiccator and cool for 15 minutes, or longer. Obtain dry weight of sample by transferring it to tared scoop and weighing on analytical balance. Record the dry weight.

6. Transfer the disks to a Kjeldahl flask of 300-ml. capacity.

7. Drop 2 glass beads or one porous granule into the flask; add ⅓ of a small horn spoonful of potassium sulfate (K_2SO_4) powder. Introduce 4 ml. of Reagent 15, total N with the special pipette. Let stand for about 5 minutes. (Where an efficient hood to exhaust noxious fumes from the laboratory is not available, fit a Hengar tube into the neck of the flask.)

Place the Kjeldahl flask on the heater to digest; digest for ½ hour. Using the wooden clamp, remove flask to the box and cool to room temperature. Add 100 ml. of Reagent 18, total N from a graduated cylinder, washing down the neck of the Kjeldahl flask. Let stand to cool.

Add 15 ml. of Reagent 16, total N to a 200x29 mm. calibrated test tube. Immerse in cold water in a 500-ml. Erlenmeyer flask. Set flask and tube on iron support shelf and arrange this unit adjacent to heater unit for the distillation.

With the solution in the Kjeldahl flask at room temperature, add 20 ml. of Reagent 17, total N from the special dispensing burette. Turn on heater current.

Immediately attach the connecting bulb assembly, stoppering "trap end" tightly with the flask. The outlet tube is put into the test tube with the tip momentarily withheld above the level of Reagent 16, total N while the mixture in the Kjeldahl flask is stirred thoroughly. After mixing, the tip of the distillation outlet tube is immersed in the 15 ml. of Reagent 16, total N.

Place the Kjeldahl flask on the heater. Distillation is continued until the distillate reaches the level marked on the test tube, when the water flask and tube are immediately removed from the distillation outlet. The heater may then be turned off and the connecting bulb assembly removed. The test tube is removed from the Erlenmeyer flask and placed on the tube rack to cool. Cool distillate to room temperature.

8. Make volume exactly up to the 50-ml. mark with Reagent 18, total N. *(Note:* Distillate may also be collected following the procedure outlined under the modification suggested for "Total Nitrogen.") Stopper test tube with a No. 6 rubber stopper and mix contents thoroughly by inverting several times.

(a) In general, a mixture of 1 ml. of distillate plus 5 ml. of Reagent 18, total N and an 0.50 ml. of distillate plus 5 ml. of Reagent 18, total N will cover the range of nitrogen found in the sample. However, the table of readings to follow will cover any extremes, provided approximately 60-disk samples are taken.

9. (a) Using a special 1-ml. (calibrated to 0.1 ml.) Mohr pipette, transfer 1-ml. aliquots of the distillate to each of two comparison vials. Add 5 ml. of Reagent 18, total N with a special 5-ml. Mohr pipette. Add 1 ml. of Reagent 6, N to each tube. Stopper and let stand 1 minute; mix if necessary. Then compare with color standards on the illuminator.

(b) Repeat procedure with another set of two vials, but use an 0.50-ml. aliquot of the distillate plus 5 ml. of Reagent 18, total N.

(c) When proficiency in reading and matching color standards has been attained, the two different proportional mixtures may be made up at one time, developed, allowed to stand the 1-minute interval and then read.

(d) The other dilutions listed in the table of readings (0.25 ml. of distillate plus 5 ml. of Reagent 18, total N and 1.5 ml. of distillate plus 4.5 ml. of Reagent 18, total N) are only to be used when the 1-ml. and 0.5-ml. aliquots are unsatisfactory because of a too light or too dark color development. Standard tubes which give most satisfactory results are those between 3 and 6, inclusive.

10. Refer to the table of readings for data on the percentage of nitrogen in cane leaves. (The fractions between standard numbers of the table refer to the position of the unknown to its approximate matching between two adjacent standards.)

11. Refer to the table of factors for dry weight.

12. Factor *times* Reading = per cent total N (dry basis). The average of the two percentages will give the result for the analysis of the sample.

Field Variety Fert. N

Acres Crop P_2O_5

Sta. No. K_2O

Date Spld.	Age Spld.	Growth Measurements						N - Index		Average	

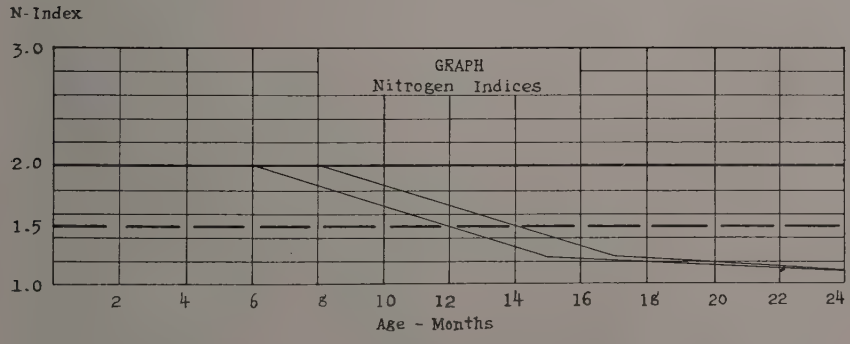


Fig. 1

Example:

(*a*) Dry weight of sample=0.0812 gram

(*b*) Distillate analysis, Reading:
Dilution 1 and 5=0.180 Reading
Dilution ½ and 5=0.176 Reading

(*c*) Referring to table of factors for dry weight,
0.081 gram, Factor=12.3

(*d*) Per cent total N=Factor *times* Reading
1 ml.+5 ml. dilution—12.3×0.180=2.21% total N
0.5 ml.+5 ml. dilution—12.3×0.176=2.16% total N } 2.19%

(*e*) or averaging the two Readings:
0.180
0.176 } 0.178 (average reading)
and multiplying by Factor:
0.178×12.3=2.19% (result for the sample).

A form has been developed for recording the leaf-punch nitrogen data obtained in this type of study. It is illustrated in Fig. 1. Spaces are provided for data pertinent to field, crop and fertilization. Tabular columns are included for recording date of sampling, age of cane at sampling, growth measurement data if taken, the nitrogen index values and remarks. At the bottom of the page a form is appended for plotting a graphical presentation of the nitrogen data. The nitrogen percentages are placed on the ordinate and the age in months on the abscissa.

TABLE OF READINGS FOR N DETERMINATION IN LEAF-PUNCH SAMPLES WHERE ENTIRE SAMPLE IS DISTILLED

(Dilutions below, refer to treatment of distillate)

Standard No.	Dilution			
	1 ml.+5	0.50 ml.+5	0.25 ml.+5	1.5 ml.+4.5
1	.012	.022	.042	.008
.25	.018	.033	.063	.012
.50	.024	.044	.084	.016
.75	.030	.055	.105	.020
2	.036	.066	.126	.024
.25	.042	.077	.147	.028
.50	.048	.088	.168	.032
.75	.054	.099	.189	.036
3	.060	.110	.210	.040
.25	.066	.121	.231	.044
.50	.072	.132	.252	.048
.75	.078	.143	.273	.052
4	.084	.154	.294	.056
.25	.090	.165	.315	.060
.50	.096	.176	.336	.064
.75	.102	.187	.357	.068
5	.108	.198	.378	.072
.25	.117	.215	.410	.078
.50	.126	.231	.442	.084
.75	.135	.248	.473	.090
6	.144	.264	.504	.096
.25	.153	.281	.536	.102
.50	.162	.297	.567	.108
.75	.171	.314	.598	.114
7	.180	.330	.630	.120
.25	.195	.358	.682	.130
.50	.210	.385	.735	.140
.75	.225	.413	.788	.150
8	.240	.440	.840	.160

The above data are merely readings. To obtain per cent total nitrogen (dry basis) in the sample, multiply Reading by Factor for dry weight.

Reading *times* Factor=% total N (dry basis).

TABLE OF FACTORS FOR DRY WEIGHT

The following factors are obtained by the formula:

$$\text{Factor (F)} = \frac{1}{\text{Dry weight of sample}}$$

Dry weight	Factor	Dry weight	Factor	Dry weight	Factor
.040	25.0	.060	16.7	.080	12.5
.041	24.4	.061	16.4	.081	12.3
.042	23.8	.062	16.1	.082	12.2
.043	23.2	.063	15.9	.083	12.0
.044	22.7	.064	15.6	.084	11.9
.045	22.2	.065	15.4	.085	11.8
.046	21.7	.066	15.1	.086	11.6
.047	21.2	.067	14.9	.087	11.5
.048	20.8	.068	14.7	.088	11.4
.049	20.4	.069	14.5	.089	11.2
.050	20.0	.070	14.3	.090	11.1
.051	19.6	.071	14.1	.091	11.0
.052	19.2	.072	13.9	.092	10.9
.053	18.9	.073	13.7	.093	10.8
.054	18.5	.074	13.5	.094	10.6
.055	18.2	.075	13.3	.095	10.5
.056	17.8	.076	13.2	.096	10.4
.057	17.5	.077	13.0	.097	10.3
.058	17.2	.078	12.8	.098	10.2
.059	16.9	.079	12.6	.099	10.1
.060	16.7	.080	12.5	.100	10.0

New R.C.M. Procedures

Rapid Estimation of Total Phosphate in Soils:

Weigh 0.25 gram of 100-mesh soil into a 60-ml. glazed porcelain dish. Add 2 to 2.5 grams of flux ($2Na_2CO_3 + 1Li_2CO_3$) in about 3 portions, intimately mixing each addition with a glass rod.

To a 40-ml. nickel crucible, add a thin layer of the flux and press down lightly. Transfer the prepared mixture from the dish with a spatula and cover it with an additional thin layer of flux.

Cover the crucible and fuse on the Type "H" electric hot plate at full heat. Continue heating until all bubbling ceases (½ hour). Remove the crucible from heater, using tongs, and give a rotary motion to the fused mass so that most of it will solidify on the sides of the crucible. (This procedure will facilitate the solution of the solid mass which, after cooling, is placed in a 250-ml. beaker.)

Place the crucible with its contents and cover in a 350-ml. beaker containing 75 ml. of H_2O and approximately 1 gram of ammonium carbonate. After boiling gently for about 5 minutes, remove and hold the crucible and lid separately over the beaker and wash each carefully with distilled water, making sure that all the washings are collected in the beaker. Break up with the glass rod any insoluble residue adhering to the crucible or cover.

Filter the solution in the beaker through a Munktell No. 0, 11-cm. filter paper and wash the filter and residue thoroughly with hot water, reserving all filtrate and washings in the receiving beaker.

Evaporate filtrate almost to dryness (avoid spattering) with 2 ml. of con-

centrated HCl. (Acid to methyl red or methyl orange indicator.) Add 20 drops of Reagent 11, P_2O_5 and evaporate again. Repeat evaporation with 2 ml. of concentrated HCl.

Eliminate excess bromine with a few drops of HNO_3 and evaporate to dryness. Repeat evaporation with 2 ml. of concentrated HCl. Evaporate to dryness twice more with 1 ml. of concentrated HCl.

Take up the evaporated residue in the beaker with exactly 50 ml. of Reagent 4, P_2O_5. Insure complete solution of residue by stirring with a glass rod. If insoluble substance (SiO_2) persists, filter through a wad of clean, dry cotton. This clear filtrate is now ready for P_2O_5 determination by the regular R.C.M. for phosphate.

Pipette with a 5- or 10-ml. Mohr pipette a suitable aliquot, ranging from 1 to 8 ml., into a phosphate comparison tube. (Make up the aliquots to a total volume of 8 ml. with Reagent 4, P_2O_5 on all comparisons.) Mix the contents of the tube thoroughly.

Add one drop of stannous chloride solution to the tube, mix again and immediately compare with the phosphate color standards for cane juice, using the phosphate illuminator. Note result. Continue with the addition of stannous chloride solution, drop by drop, until a maximum blue color is developed. After the addition of each drop of stannous chloride solution, cover the open end of the vial with finger, rock back and forth, and immediately compare with the standards.

Record the result obtained by the maximum blue color as per cent P_2O_5 by referring to the table for total phosphate in soils. Employ the technic of selecting aliquots for comparison as indicated in the example given below. If possible, select aliquots which will develop a color intensity comparable to standard tubes Nos. 4 to 8, inclusive.

Example: If a 5-ml. aliquot approximately matches Tube No. 4, giving 0.32 per cent, check the result by selecting aliquots from the table which gives percentages in the vicinity of 0.32 per cent, such as:

ml. aliquot	%	Std. tube No.
5.00	0.32	4
5.25	0.31	4+
5.50	0.29	4+
5.75	0.33	5—
6.00	0.32	5
6.25	0.31	5+
6.50	0.30	5+
6.50	0.34	6—
6.75	0.33	6—
7.00	0.32	6
7.25	0.31	6+
7.50	0.30	6+
7.75	0.33	7—

Rapid Determination of Phosphate (P_2O_5) in Cane Root Material:

Preparation of Sample: Obtain fresh root material and wash off any adhering soil particles or foreign matter. Dry in an electric drying oven at about 100° C.

RAPID ESTIMATION OF TOTAL PHOSPHATE IN SOILS

0.25-gram soil fusion extract made up to 50 ml.—Figures in % phosphate, P_2O_5

	ml. aliquots														
Std. No.	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75
1.....	0.64	0.512	0.427	0.366	0.32	0.284	0.256	0.233	0.213	0.197	0.183	0.171	0.160	0.151	0.142	0.135
2.....	0.96	0.768	0.640	0.549	0.48	0.427	0.384	0.349	0.320	0.295	0.274	0.256	0.24	0.226	0.213	0.202
3.....	1.28	1.204	0.853	0.731	0.64	0.569	0.512	0.465	0.427	0.394	0.366	0.341	0.32	0.301	0.284	0.269
4.....	1.60	1.280	1.067	0.914	0.80	0.711	0.640	0.582	0.533	0.492	0.457	0.427	0.40	0.376	0.356	0.337
5.....	1.92	1.536	1.280	1.097	0.96	0.853	0.768	0.698	0.640	0.591	0.549	0.512	0.48	0.452	0.427	0.404
6.....	2.24	1.792	1.493	1.280	1.12	0.996	0.896	0.815	0.747	0.689	0.640	0.597	0.56	0.527	0.498	0.472
7.....	2.56	2.048	1.707	1.463	1.28	1.138	1.024	0.931	0.853	0.788	0.731	0.683	0.64	0.602	0.569	0.539
8.....	2.88	2.304	1.920	1.646	1.44	1.280	1.152	1.047	0.960	0.886	0.823	0.768	0.72	0.678	0.640	0.606

	ml. aliquots												
Std. No.	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00
1.....	0.128	0.122	0.116	0.111	0.107	0.102	0.098	0.095	0.091	0.088	0.085	0.083	0.080
2.....	0.192	0.183	0.175	0.167	0.160	0.154	0.148	0.142	0.137	0.132	0.128	0.124	0.12
3.....	0.256	0.244	0.233	0.223	0.213	0.205	0.197	0.190	0.183	0.177	0.171	0.165	0.16
4.....	0.320	0.305	0.291	0.278	0.267	0.256	0.246	0.237	0.229	0.221	0.213	0.206	0.20
5.....	0.384	0.366	0.349	0.334	0.320	0.307	0.295	0.284	0.274	0.265	0.256	0.248	0.24
6.....	0.448	0.427	0.407	0.390	0.373	0.358	0.345	0.332	0.320	0.309	0.299	0.289	0.28
7.....	0.512	0.488	0.465	0.445	0.427	0.410	0.394	0.379	0.366	0.353	0.341	0.330	0.32
8.....	0.576	0.549	0.524	0.501	0.480	0.461	0.443	0.427	0.411	0.397	0.384	0.372	0.36

Note: Use comparison tubes of uniform volume in all determinations.

for 3 hours. Grind the dried roots in order to obtain a uniform representative sample for analysis.

Procedure: Weigh out 0.36 gram of the ground root material into a 50-ml. beaker.

Add 1 ml. of Reagent 12, P_2O_5* and insure a good mixture by stirring with a short glass rod. Make a special effort to have the greater portion of the sample at the bottom of the beaker since it will have a tendency to adhere to the sides of the beaker.

Now add 5 drops of concentrated HNO_3 from a dropping bottle, covering as much area as possible. Place the beaker on an open Type "H" electric hot plate (directly upon the coils) and ignite for 5 minutes or until white or gray-colored ash appears.

Remove and cool, then add a few drops (about 10 drops) of concentrated HNO_3 and mix in such a way that the non-ashed root material (usually dark colored) will be at the bottom of the beaker.

Place on an electric hot plate and evaporate to dryness. Then ignite again on the open Type "H" electric heater for 5 minutes. Ash should be nearly white or gray in color.

Cool the ashed material and add 5 drops each of concentrated HNO_3 and HCl. Evaporate to dryness on an electric hot plate. If residue is brown or dark colored, repeat the hydrochloric and nitric acid treatments.

When a yellow-colored or clear residue is obtained, add 5 drops of concentrated HCl and evaporate to dryness. Dissolve the residue in 20 ml. of N/2 hydrochloric acid solution and filter through Munktell No. 3, 7-cm. filter paper.

Pipette 15 ml. of the filtrate into a 100-ml. beaker and evaporate to dryness. Add 15 ml. of Reagent 4, P_2O_5 to the cooled residue and stir thoroughly.

Using a 5-ml. Mohr pipette, transfer 5 ml. of the solution into a phosphate vial and make up to 8 ml. with Reagent 4, P_2O_5. (For all subsequent aliquots taken for comparison, bring the volume up to 8 ml. with Reagent 4, P_2O_5.)

Develop blue color with an appropriate amount of stannous chloride solution and compare with the phosphate color standards for cane juice. (Use the regular R.C.M. technic for color development.) When the developed color does not match any standard tube, make an estimation of the percentage of P_2O_5 and verify the result by selecting aliquots from the table which will exactly match with a standard tube, preferably between standard tubes Nos. 3 to 6, inclusive.

Example:

5-ml. aliquot plus 3 ml. of Reagent 4, P_2O_5 matches color about ½ way between standard tubes Nos. 4 and 5.

Referring to the table and interpolating,

Tube No. 4—0.089 per cent

Tube No. 5—0.107 per cent

The percentage ½ way between them is 0.098 per cent.

Again referring to the table, 4.5-ml. aliquot with Tube No. 4 gives 0.099 per cent.

For confirmatory test, take a 4.5-ml. aliquot from the test solution, add 3.5 ml. of Reagent 4, P_2O_5 and make comparison. If the interpolation is correct, the color developed should match Tube No. 4.

* This reagent is prepared by dissolving 100 grams C.P. magnesium nitrate, $Mg(NO_3)_2 \cdot 6H_2O$, in 100 ml. of distilled water.

Should the developed color be more intense than tube No. 8 (greater than 0.16 per cent), dilute the remaining test solution by adding to it an equal volume of Reagent 4, P_2O_5, i.e., if 10 ml. of solution remains, add 10 ml. of Reagent 4, P_2O_5. Stir solution thoroughly.

Proceed with the color development of the 1 — 1 diluted solution. Multiply the result by 2 for percentages on the diluted solution.

PERCENTAGE OF P_2O_5 IN ROOT MATERIAL

(On moisture-free basis)

Aliquots	Standard Tube Nos.							
ml.	1	2	3	4	5	6	7	8
5.00	.035	.053	.071	.089	.107	.124	.142	.160
4.75	.037	.056	.075	.094	.112	.131	.150	.168
4.50	.039	.059	.079	.099	.118	.138	.158	.178
4.25	.042	.063	.084	.105	.125	.146	.167	.188
4.00	.044	.067	.089	.111	.133	.156	.178	.200
3.75	.047	.071	.095	.118	.142	.166	.190	.213
3.50	.051	.076	.102	.127	.152	.178	.203	.229
3.25	.055	.082	.109	.137	.164	.191	.219	.246
3.00	.059	.089	.119	.148	.178	.207	.237	.267

(To obtain results on a 1 + 1 diluted solution, multiply percentages given in the above table by 2.)

Colorimetric Method for the Determination of Sulfate in Cane Juice:

The colorimetric method described utilizes the color formed by sodium rhodizonate and the excess barium chloride which is used to precipitate the sulfate in the sample.

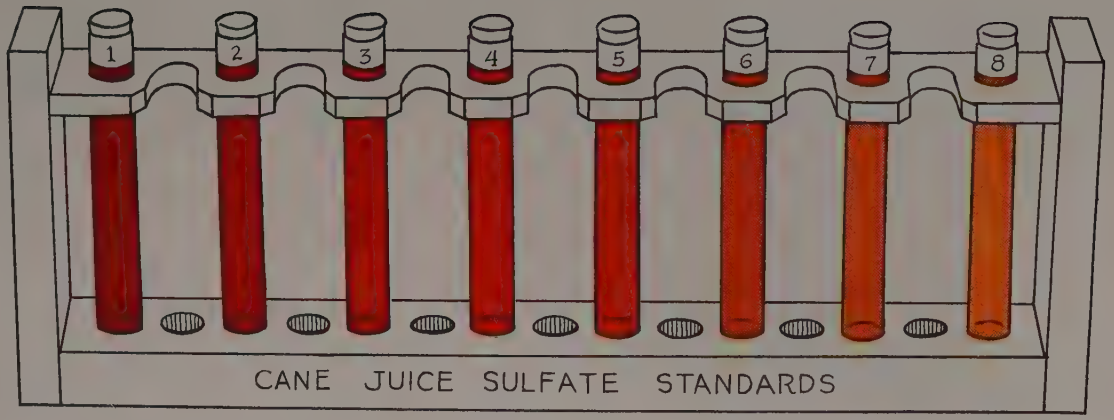
In brief, the method follows: 0.50 ml. of 0.01 N barium chloride solution is added to a measured portion of the juice sample which is placed in a tall vial (phosphate type). The contents of the vial are shaken for ten seconds, allowed to stand one-half minute, made up to 7.0 ml. with distilled water and thoroughly mixed. Three fourths of a ml. of a freshly prepared 0.1 per cent aqueous solution of sodium rhodizonate is added and the contents again mixed to develop the color. The sodium rhodizonate forms a red solution with the excess barium. If there is no excess barium chloride, the solution is yellow.

A set of eight permanent inorganic standards, Plate I, has been prepared to cover the range of colors developed. The test solution is compared with the sulfate standards in front of a phosphate illuminator. A table gives the sulfate content in terms of parts per million sulfate for various aliquots of the sample which match each of the standard tubes.

It is necessary to follow precisely the proportions given in the method when using the standards described below. After exhaustive study, the concentrations and proportions of reacting substances given in the following detailed procedure were found to be most satisfactory.

The sealed tubes of color standards are arranged in the order of increasing sulfate content, the lowest being at the extreme left. They are placed in a wooden rack and are numbered progressively from one to eight, the lower figure denoting lower sulfate content.

Unknown solutions in open vials are placed in the intervening spaces and the whole assembly is placed in front of a standard source of illumination for comparison. Reference is made to a suitably prepared table for analytical values. The standards are made from an inorganic salt and are permanent. Full details of preparation, standardization and evaluation appear in the text.


1
2
3
4
5
6
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8
CANE JUICE SULFATE STANDARDS

Permanent Inorganic Color Standards: In the search for permanent soluble inorganic salts, or combinations of these, to match the colors developed in the test vials in the determination of sulfate we encountered unusual difficulties because the red-colored barium rhodizonate was mixed with small crystals of white barium sulfate. This mixture produced a tinted turbidity instead of clear-colored solutions.

The nearest approximations to the regularly developed test solutions were obtained by etching the outer surfaces of the vials in which the inorganic solutions were sealed. The etching was effected by dipping the stoppered vial, previously treated with cleaning solution, for five minutes in a proprietary etching compound (Jack Frost).

Preparation of Standards: A concentrated aqueous solution of sodium dichromate is used as the base for the standards. Dissolve 250 grams of C.P. sodium dichromate ($Na_2Cr_2O_7.2H_2O$) in distilled water and make up to a total volume of 250 ml. This is Solution *A*. Filter.

Column 2 of Table I shows the quantity of this concentrate to use in making 100 ml. of each standard solution. Column 3 indicates the treatment given the vials in which the inorganic solutions are sealed. The sealing is effected by pouring molten paraffin into the vial filled within 20 mm. of the top with standard solution. A rubber stopper may be pushed into the opening, in which case a little air space is left between the stopper and the paraffin.

TABLE I

Sulfate standard No.	ml. Solution A per 100 ml. of standard	Vial treatment	SO_4 equiv. of standard, in milligrams
1	100	Outer surface etched five minutes by "Jack Frost"	0.048
2	85		0.072
3	63		0.096
4	45		0.120
5	28		0.144
6	12		0.168
7	5		0.192
8	1.5	Unetched tube	0.216

Column 4 gives the sulfate equivalent in milligrams SO_4 of each standard. In Fig. 2, the sulfate content is plotted against the concentration of sodium dichromate in the standards. The smooth curve shows the regularity of the change of color to sulfate content and also serves as a confirmation of the figures experimentally obtained.

Equipment Required:

1 set sulfate color standards in box
6 beakers, Pyrex glass, 100-ml. capacity
6 funnels, glass, 90-mm. diameter
1 volumetric flask, Exax, 10-ml. capacity
1 volumetric flask, Exax, 25-ml. capacity
1 vial block

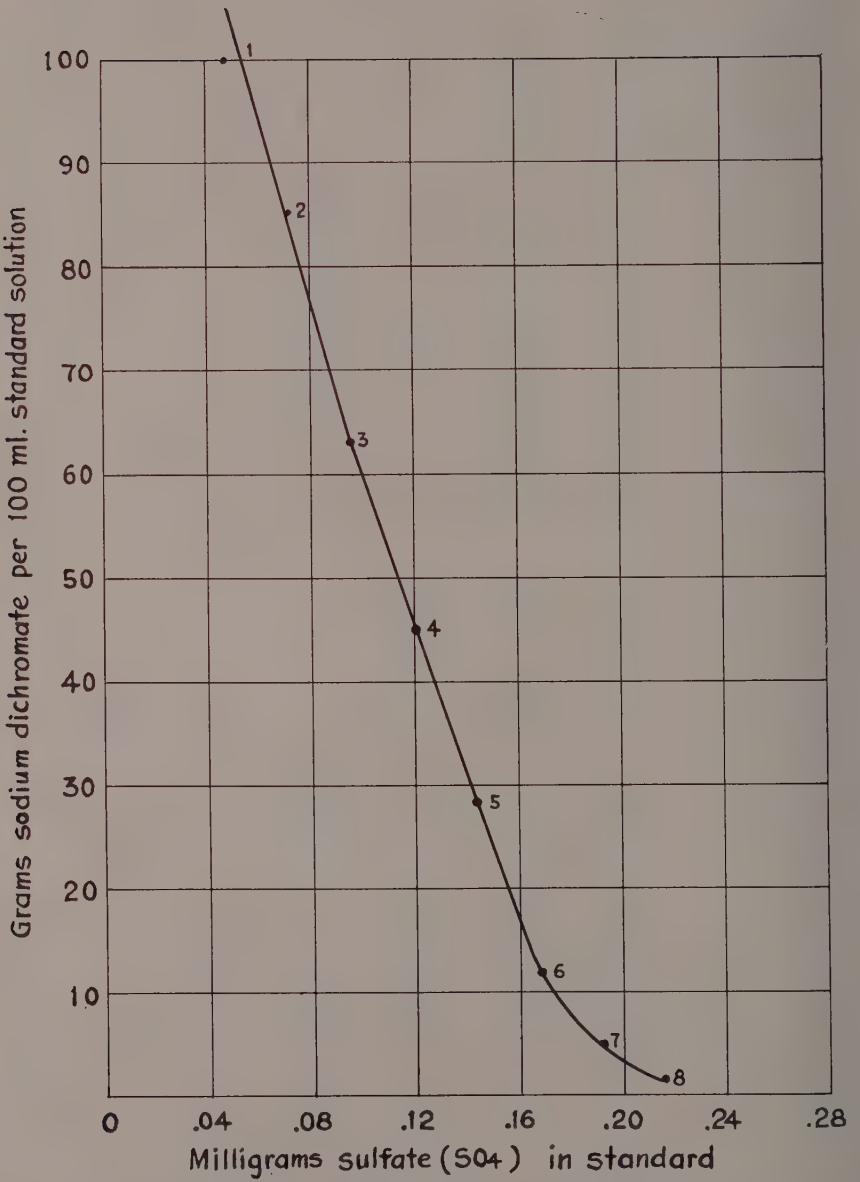

Fig. 2. Graph showing grams of sodium dichromate required to make 100 ml. of each sulfate standard and its sulfate equivalent in mg of SO_4.

1 burette, Exax, 50-ml. capacity, for distilled water
1 box Whatman No. 12, 15-cm. folded filter paper
1 funnel rack, 10-hole
1 phosphate illuminator
2 pipettes, Mohr, 1-ml. capacity, graduated to 0.01 ml.
12 vials, shell, tall-form, calibrated to 7.0 ml.
1 special pipette, 0.75-ml. capacity, with rubber bulb.

Preparation of Special Equipment Required: The tall-form shell vials are calibrated by filling from a 25-ml. burette to 7.0 ml. To prepare the special pipette, draw glass tubing of 7 mm. external diameter to a tip. It is calibrated by counting the number of drops equivalent to 1 ml., then drawing up 1 ml. from a 10-ml. calibrated graduate and letting out one-fourth of the number of drops determined. Scratch a mark at the 0.75-ml. point. Enlarge the upper end to accommodate a small rubber bulb.

Reagents: Sulfate Reagent No. 28, 0.01 N Barium Chloride: Weigh out 1.2216 grams barium chloride ($BaCl_2.2H_2O$), wash into a liter volumetric flask and make up to the mark with distilled water. Preferably, make up a liter of tenth normal barium chloride solution and dilute 100 ml. to 1 liter.

Sulfate Reagent No. 29, 0.1 Per Cent Aqueous Solution of Sodium Rhodizonate: This reagent must be freshly prepared. It loses strength gradually and can be used for only a few hours. Portions of the salt are weighed out into small glass tubes. Take the amount needed and wash completely with distilled water into the size volumetric flask indicated. Make up to volume, stopper and shake until dissolved. Three-fourths ml. of the reagent added to 7.0 ml. of distilled water in the tall vial used for developing the color matches standard No. 8. If the preceding test shows a difference in the shade, the reagent must be discarded.

Procedure: The volume of the samples tested and also of the various reagents used must be measured accurately. Since the volumes employed are exceedingly small, it is necessary to remove any liquid clinging to the outer surface of the pipettes before inserting the latter into the vials. A clean piece of filter paper is suggested for this purpose. Likewise, before the transfer, the tip of the pipette should be touched to the outer surface of the vial and, after the transfer, to the inner surface. This insures more accurate results.

Use fresh, untreated juice or juice to which has been added the preservative employed in rapid chemical methods. Mix the juice thoroughly and filter through Whatman No. 12, 15-cm. folded filter paper. Transfer 0.20 ml. of the juice by means of a 1-ml. Mohr pipette, graduated to 0.01 ml., *to the bottom* of a tall vial (phosphate type).

Add 0.50 ml. of sulfate Reagent No. 28 by means of a pipette, similar to the one used above, to the bottom of the vial containing the juice—shake the contents for ten seconds. Allow the vial to stand ½ minute and dilute with distilled water to the 7.0-ml. mark. Stopper with finger and mix by inverting three times.

Add 0.75 ml. of sulfate Reagent No. 29, using a specially calibrated pipette for the purpose. Mix by inverting the vial three times. Let stand for 10 seconds, then compare with the aid of the phosphate illuminator against the sulfate standards.

If the developed solution is too red, use more juice and repeat the procedure; if the solution is too yellow, use less juice and repeat the procedure.

Use as many aliquots as possible, the colors of which fall within the range of the sulfate standards. Record all the readings. Refer to Table II which gives the sulfate concentration in terms of parts per million for various aliquots used. For the final result, take the average of the figures for the aliquots matching standard No. 3 to standard No. 8, inclusive.

TABLE II

COLORIMETRIC DETERMINATION OF SULFATE IN CANE JUICE

Sulfates (SO_4=) in parts per million

Standard No.	ml. sample used														
	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.60	.70	.80	.90	1.00
1	960	480	320	240	192	160	137	120	107	96	80	69	60	53	48
2	1440	720	480	360	288	240	206	180	160	144	120	103	90	80	72
3	1920	960	640	480	384	320	274	240	213	192	160	137	120	107	96
4	2400	1200	800	600	480	400	343	300	266	240	200	171	150	133	120
5	2880	1440	960	720	576	480	411	360	320	288	240	206	180	160	144
6	3360	1680	1120	840	672	560	480	420	374	336	280	240	210	187	168
7	3840	1920	1280	960	768	640	548	480	426	384	320	274	240	213	192
8	4320	2160	1440	1080	864	720	617	540	480	432	360	309	270	240	216

Comparison of Results: The method has been applied to a number of representative cane juices secured in visits made to all of the plantations on Oahu. Both fresh and preserved juices were analyzed by the colorimetric method described and also by the regular gravimetric method. The results are shown in Table III. It will be noted that although the colorimetric results vary somewhat from the gravimetric figures, the variation is within the limits of the change from one standard to the next.

TABLE III

Juice No.	Plantation	Variety	Treatment of sample	p.p.m. sulfate (SO_4=) Gravimetric	p.p.m. sulfate (SO_4=) Colorimetric
1	Honolulu	31–2538	Fresh	1370	1450
2	Honolulu	31–2538	R.C.M. preservative	1350	1410
3	Oahu	H 109*	Fresh	868	886
4	Oahu	H 109*	Fresh	1026	1000
5	Oahu	28–3540	Preserved	576	592
6	Ewa	H 109	Fresh	1112	1320
7	Ewa	H 109	Preserved	1142	1200
8	Kahuku	H 109	Fresh	1064	1220
9	Kahuku	H 109	Preserved	1066	1160
10	Waianae	H 109	Fresh	1020	1160
11	Waianae	H 109	Preserved	1014	1130
12	Waialua	H 109	Fresh	822	910
13	Waialua	H 109	Preserved	834	906
14	Waialua	H 109	Fresh	710	735
15	Waialua	H 109	Preserved	756	705

* Tops included.

The Effects of Oven Drying and Air Drying on the Available Nitrogen Content of Soils:

At the time a field crop of sugar cane is harvested the soil in the field, as a

rule, is quite low in its concentration of "available" or readily soluble nitrogen. Immediately thereafter, however, upon exposure of the bare field to sunlight (warmth) and moisture, bacterial action appears to be stimulated and the formation of available nitrogen occurs from insoluble organic sources in the soil.

As a companion determination to the progressive sugar cane leaf-punch nitrogen field survey, an appraisal of the status of available soil nitrogen, at any given moment, is highly desirable. It is common knowledge, however, that by the time representative soil collections can be made, dried and composited for analysis a delay of ten days or longer will have ensued and the available nitrogen concentration will have been markedly changed. Either one of these conditions defeats the purpose of the determination.

Therefore an attempt has been made (a) to ascertain the shift in soil nitrogen availability as brought about by various methods of artificial and natural drying of the soil specimen, and (b) to develop a rapid method of measuring soil nitrogen availability with fair accuracy in the shortest possible space of time immediately following the sampling of the field soil.

As a general rule, soils intended for analysis are air dried before they are disintegrated, sieved, mixed and prepared for the analyst. Soils taken from the field may vary from saturation with moisture to a wetness below the wilting coefficient. On some plantations, or in localities of high humidity, air drying of some soils may require days or even weeks. Hence, if drying is an analytical prerequisite, rapidity of drying is a necessity unless other methods of making the determination be found.

Obvious methods of drying soil are to place the sample in an oven at controlled temperature or near sources of warmth in the sugar factory. We shall consider the extent of the changes, if any, that take place in the ammoniacal, nitrate and *total available* nitrogen content of soils when they are dried by various means and for different periods of time.

Experimental: Temperatures were determined at which it was found possible to dry soils in a short time, say, between an hour and twenty-four hours. Analyses of the samples were made immediately after drying by means of the rapid chemical methods. This procedure would indicate any increases of available nitrogen which may have developed due to heating, and also it should show the extent of such changes brought about by the heating.

Preliminary tests with soils Nos. 27 and 91 indicate that at 105° C. these samples were sufficiently dry to be workable in about one hour. At 60° C., twenty-four hours or longer were necessary to secure comparable drying. These two temperatures were therefore selected to produce what may be considered good indications of the changes which may take place in the available nitrogen of soils when so treated. For this purpose a representative number of soils were selected which are known to be difficult to dry.

In order to study the effect of prolonged heating at these temperatures, other portions were dried at intervals in the oven, some for as long as two continuous weeks. Comparative figures were also obtained on air-dried and wet portions of these soils. The air drying was carried out in the shade at room temperature. The method used to sample the wet soil is set forth in the appended procedure. The analytical data are discussed separately under (a) ammoniacal, (b) nitrate and (c) the sum of the two, or total available nitrogen.

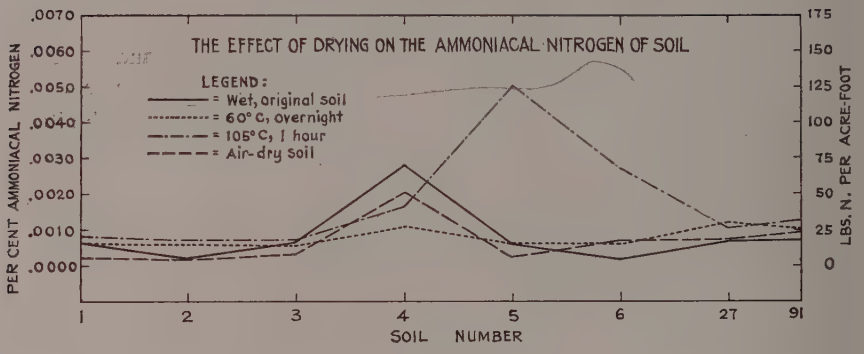

Fig. 3

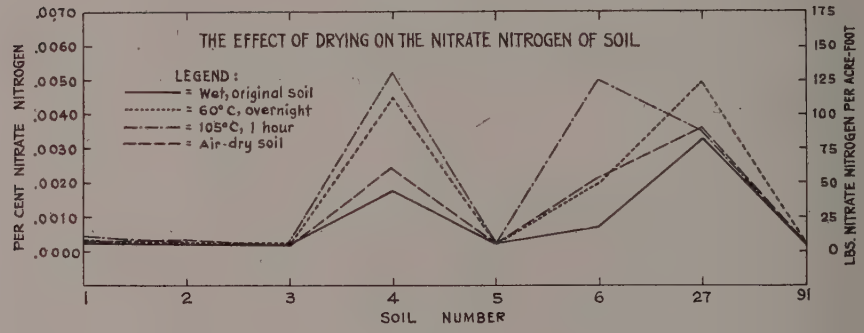

Fig. 4

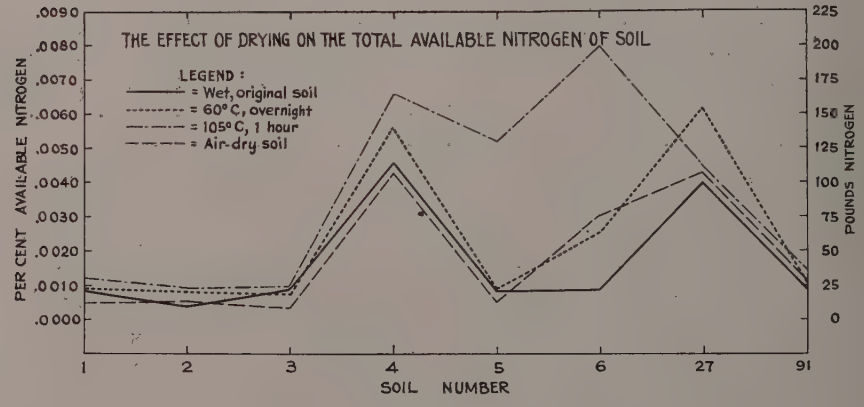

Fig. 5

Ammoniacal Nitrogen: Comparisons of the ammoniacal nitrogen content of the soils studied show that the air-dried portions are, in most cases, slightly lower in ammonia nitrogen than the moist, original specimens (Fig. 3 and Table IV). The changes found were less than 25 pounds per acre-foot in the eight soils studied. Minor differences were also noted when the soils were heated overnight in an oven below 60° C. These soils were not completely or sufficiently dried. One sample, No. 4, decreased by 40 pounds ammonia nitrogen per acre-foot compared with the wet soil, but this ammonia was apparently nitrified and not lost, for the nitrate nitrogen increased by the same amount. When the drying period was advanced to 40 hours, there were small gains observed generally. However, samples kept in the oven at 60° C. for two weeks increased tremendously in ammonia nitrogen in every case. The gains ranged from 65 pounds to 300 pounds nitrogen per acre-foot.

On drying for one hour at 105° C., the changes in the ammoniacal nitrogen content varied from a 30-pound decrease to an increase of over 100 pounds (soil No. 5). The decrease in one soil (No. 4) is traceable to nitrification which also occurred at 60° C. However, when the soils were left in an oven over a weekend (about 65 hours) at the higher temperature, significant increases of 50 pounds to over 200 pounds nitrogen per acre-foot took place in every case. These figures show that an increase in temperature and also in the period of heating markedly step up the concentration of ammoniacal nitrogen in these soils. Below 60° C., where it is necessary to dry for twenty-four hours or longer, slight to over 25-pound increases of ammonia nitrogen were found. At the higher temperature of 105° C. for one hour, very great changes may thus be expected in some soils. For this reason temperatures as high as 105° C. can not be used to dry soils for the determination of field availability in ammoniacal nitrogen. Extended heating at elevated temperatures is especially to be avoided, even temperatures as low as 50° C. to 60° C. Under these conditions the factors favoring ammonification are intensified and predominate and large increases of ammonia generally prevail. Such conditions, of course, do not exist in the fields.

Nitrate Nitrogen: The nitrate form of nitrogen is generally not affected much by temperature changes or by extended heating. In the two soils, Nos. 4 and 6 (Table V and Fig. 4), in which large increases of nitrate nitrogen do occur upon heating, it may be explained, perhaps, as due to the acceleration of the natural processes of nitrification. By the subsequent reanalyses of all samples, the wet soils were found to have increased in nitrate nitrogen to the high levels reached by the samples dried by the various methods described. In soil No. 4, the gain is apparently due to nitrification of the ammoniacal nitrogen originally present in the wet soil and in No. 6, to nitrification of organic matter.

Nitrification appears to be accelerated in the early stages of heating and ammonification in the later stages.

Total Available Nitrogen: Total available nitrogen, i.e., the sum of the ammoniacal and nitrate forms, in naturally wet soils appeared to change only slightly, if any. Exceptions were found, however. In one wet soil, No. 6 (Table VI and Fig. 5), the total available nitrogen increased by about 50 pounds per acre-foot when the soil was air dried. This gain is due to an increase of both the ammoniacal

TABLE IV

PER CENT AMMONIACAL NITROGEN

Lab. No.	Description of samples	Specimens analyzed	Treatments: Air-dry soil	Wet orig. fld. soil	Below 60° C.: Over-night	40 hrs.	2 wks.	105° C.: 1 hr.	60 hrs.
1	Honolulu Plantation Co., near poi factory	Immediately after treatment	.0002	.0006	.0006	.0007	.0050	.0008	.0028
		After 2 weeks	.0002	.0002	.0002	.0006	.....	.0006	.....
2	Expt. Stn. Seedling Station, Ewa	Immediately after treatment	.0002	.0002	.0006	.0009	.0028	.0007	.0026
		After 2 weeks	.0002	.0002	.0003	.0007	.....	.0006	.....
3	Waialua Agric. Co., Ltd., Mokuleia side	Immediately after treatment	.0002	.0007	.0006	.0008	.0056	.0007	.0028
		After 2 weeks	.0004	.0002	.0006	.0006	.....	.0007	.....
4	Waialua Agric. Co., Ltd. valley soil	Immediately after treatment	.0019	.0028	.0011	.0020	.0150	.0016	+.0100
		After 2 weeks	.0021	.0002	.0011	.0018	.....	.0018	.....
5	Kahuku Plantation Co., Waialua side	Immediately after treatment	.0003	.0006	.0006	.0007	.0005	+.0050	.0030
		After 2 weeks	.0002	.0002	.0003	.0006	.....	.0050	.....
6	Kahuku Plantation Co., Punaluu	Immediately after treatment	.0008	.0002	.0006	.0012	+.0100	.0030	+.0050
		After 2 weeks	.0006	.0002	.0003	.0010	.....	.0024	.....
27	Olaa Sugar Co., Ltd., Field 4–5	Immediately after treatment	.0007	.0007	.0012	.....	.....	.0010	+.0050
		After 2 weeks	.0012	.....	.0011	.....	.....	.0010	.0040*
91	Manoa Substation, surface, Mauka of D–3	Immediately after treatment	.0009	.0007	.0010	.....	.....	.0012	+.0100
		After 2 weeks	.....	.....	.0008	.....	.....	.0011	.....

* Dried on hot plate for 10 hours.

Plus sign (+) denotes quantity more than that indicated.

TABLE V

PER CENT NITRATE NITROGEN

Lab. No.	Description of samples	Specimens analyzed	Treatments: Air-dry soil	Wet orig. fld. soil	Below 60° C.: Over-night	40 hrs.	2 wks.	105° C.: 1 hr.	60 hrs.
1	Honolulu Plantation Co., near poi factory	Immediately after treatment	.0003	.0002	.0003	.0005	.0003	.0004	.0002
		After 2 weeks	.....	.0005	.0002	.0002	.....	.0002	.0002
2	Expt. Stn. Seedling Station, Ewa	Immediately after treatment	.0003	.0002	.0002	.0002	.0002	.0002	.0002
		After 2 weeks	.....	.0005	.0002	.0002	.....	.0002	.0002
3	Waialua Agric. Co., Ltd., Mokuleia side	Immediately after treatment	.0002	.0002	.0002	.0002	.0003	.0003	.0002
		After 2 weeks	.....	.0003	.0002	.0002	.....	.0002	.0002
4	Waialua Agric. Co., Ltd. valley soil	Immediately after treatment	.0024	.0018	.0045	.0040	.0020	+.0050	.0028
		After 2 weeks	.....	.0050	.0040	.0045	.....	.0040	.0028
5	Kahuku Plantation Co., Waialua side	Immediately after treatment	.0002	.0002	.0003	.0003	.0003	.0003	.0002
		After 2 weeks	.....	.0002	.0002	.0002	.....	.0003	.0002
6	Kahuku Plantation Co., Punaluu	Immediately after treatment	.0022	.0007	.0017	.0035	.0030	+.0050	.0030
		After 2 weeks	.....	.0022	.0020	.0031	.....	.....	.0030
27	Olaa Sugar Co., Ltd., Field 4–5	Immediately after treatment	.0036	.0033	.0050	.....	.....	.0035	.0038
		After 2 weeks	.....	.....	.0045	.....	.....	.0033	.0025*
91	Manoa Substation, surface, Mauka of D–3	Immediately after treatment	.0002	.0002	.0002	.....	.....	.0002	.....
		After 2 weeks	.....	.....	.0002	.....	.....	.0002	.0002

* Dried on hot plate for 10 hours.

Plus sign (+) denotes quantity more than that indicated.

TABLE VI

PER CENT TOTAL AVAILABLE NITROGEN

Lab. No.	Description of samples	Specimens analyzed	Treatments: Air-dry soil	Wet orig. fld. soil	Below 60° C.: Over-night	40 hrs.	2 wks.	105° C.: 1 hr.	60 hrs.
1	Honolulu Plantation Co., near poi factory	Immediately after treatment	.0005	.0008	.0009	.0012	.0053	.0012	.0030
		After 2 weeks	.0005	.0007	.0004	.0008	.....	.0008	.0026
		Water added after heating	.....	.0008	.....	.0027	.....	.0042	.0072
2	Expt. Stn. Seedling Station, Ewa	Immediately after treatment	.0005	.0004	.0008	.0011	.0030	.0009	.0028
		After 2 weeks	.0004	.0007	.0005	.0009	.....	.0008	.0023
		Water added after heating	.....	.0010	.....	.0028	.....	.0042	.0102
3	Waialua Agric. Co., Ltd., Mokuleia side	Immediately after treatment	.0004	.0009	.0008	.0010	.0059	.0010	.0030
		After 2 weeks	.0006	.0005	.0008	.....	.....	.0009	.0024
		Water added after heating	.....	.0022	.....	.0042	.....	.0062	.0102
4	Waialua Agric. Co., Ltd. valley soil	Immediately after treatment	.0043	.0046	.0056	.0060	+.0170	+.0066	+.0130
		After 2 weeks	.0044	.0052	.0051	.0063	.....	.0058	+.0130
		Water added after heating	.....	.0052	.....	.0105	.....	.0105	.0122
5	Kahuku Plantation Co., Waialua side	Immediately after treatment	.0005	.0008	.0009	.0010	.0053	+.0053	.0032
		After 2 weeks	.0004	.0004	.0005	.0008	.....	.0053	.0028
		Water added after heating	.....	.0015	.....	.0040	.....	.0108	.0082
6	Kahuku Plantation Co., Punaluu	Immediately after treatment	.0030	.0009	.0025	.0047	+.0130	+.0080	+.0080
		After 2 weeks	.0024	.0024	.0023	.0041	.....	.....	.0064
		Water added after heating	.....	.0016	.....	.0058	.....	.0085	.0082
27	Olaa Sugar Co., Ltd., Field 4–5	Immediately after treatment	.0043	.0040	.0062	.....	.....	.0045	.0086
		After 2 weeks	.0052	.....	.0056	.....	.....	.0043	.0065
91	Manoa Substation, surface, Field 7	Immediately after treatment	.0011	.0009	.0012	.....	.....	.0014	+.0100
		After 2 weeks	.....	.....	.0010	.....	.....	.0013	+.0100

Plus sign (+) denotes quantity greater than that indicated.

and nitrate forms. After standing for two weeks, this particular soil gained as much as 40 pounds nitrate nitrogen. It is further observed that this soil kept in a moist condition for a period of time increased to the same nitrogen content as the air-dried portion when both were reanalyzed later. The conclusion which may be safely drawn, we believe, is that the analysis of a soil for available nitrogen in naturally wet specimens taken from the field is quite possible and gives reasonably true and accurate results. Where an apparent exception is found, as was the case in soil No. 6, it may be due to an actual change taking place during the time required to air dry the soil.

When dried overnight in an oven at 60° C., or lower, gains up to 50 pounds nitrogen per acre-foot were found. When the soils were left over a weekend in the oven at this temperature, increases ranged up to 100 pounds nitrogen per acre-foot. Samples kept for two weeks at 60° C. gained from 65 pounds available nitrogen to over 300 pounds. At a temperature of 105° C. for one hour, these soils gained from 3 pounds to over 175 pounds nitrogen and increased from 55 pounds to over 225 pounds when incubated (dried) over a weekend at 105° C.

Drying in the oven either at 60° C. or at 105° C. increases the available nitrogen content of these soils. The increases, which take place in a sizable proportion of the samples dried at 60° C. and for a short period, occur in every soil tested when dried for longer periods or at higher temperatures.

Discussion: The experimental figures, although obtained from a limited number of soils which were nevertheless a representative selection, definitely support the belief that analyses of wet field samples of soils give a truer picture of the available nitrogen supply in the field at the time of sampling than either air-dried or oven-dried portions of the same soils. This brief study was not intended to learn the causes governing the relationships found to exist between nitrogen values and various methods of soil drying, but there are sufficient data presented to point toward accelerated bacterial activity and also chemical decomposition due to the elevated temperatures employed as major causes of the increases in available nitrogen noted in the dried portions of the soils. Soils which were dried, either oven or air dried, when left standing in the dry state for a week to ten days did not change in available nitrogen as compared with their respective contents immediately after drying. (Refer to the lower figures in Tables IV, V and VI.) However, when the dried soils were kept moistened with distilled water for a week, the portions dried at 105° C. and also those dried at 60° C. for periods longer than 40 hours showed tremendous increases of available nitrogen. Although no attempt was made to keep the soils uncontaminated, those kept at 105° C. for 60 hours are apparently only partially sterilized. On the addition of moisture, the bacteria which produce ammonia increased to the greatest extent in the soils kept at the highest temperature and for the longer period. This is shown (Table IV, upper figures) in the ammonia content of the soils. The organisms detrimental to the nitrifying bacteria were not affected or destroyed when heated below 60° C. overnight.

The soils selected for this test included those extremely difficult to dry. The wet sampling method proposed is admittedly difficult to employ on these soils, but when these same soils were dried, by whichever means selected, the subsequent handling of the dry specimens was much more difficult and consumed more time

than the method suggested. This is due to the fact that the soils in question caked into a solid, rocky mass when dried.

The laboratory sampling method used, and which is recommended for handling moist or wet field-soils, is as follows:

1. If the sample taken from the field is large, spread the soil out on a wide sheet of heavy paper.
2. Break up the large masses into smaller pieces with a trowel.
3. Start from one end of the sheet and quarter by spading off a quarter of each large mass of soil and also taking one-fourth of the smaller pieces.
4. Break up the sample further and repeat Step 3 until one or two pounds are obtained.
5. Spread the sample on a square, 8-mesh wire screen (8 mesh to a linear inch) about 18 inches to a side. Press the soil with a large wooden mallet. (The screen should be made so that the wire bottom rests about three inches above the table, the screen height being about two inches or more.)
6. Press a portion of *each* part of the sample through the screen until about a tumblerful is obtained. (It is not necessary to press all of the soil through the screen.)
7. Mix by means of a spatula.
8. Fill the 10-gram soil cup by taking a small portion of soil from various parts of the mound, pack the cup solidly and level it.
9. Remove excess soil from spatula and cup.
10. Transfer the contents of the cup to a 250-ml. beaker by digging out neatly with the cleaned spatula.
11. Add 50 ml. of Reagent 5, N and stir well, using two stirring rods held together in one hand if necessary.
12. Filter through a dry filter into a 100-ml. beaker and proceed with the usual R.C.M. ammoniacal and nitrate nitrogen determinations on the filtrate.

Since the soil cup is packed solidly, the regular R.C.M. tables giving ammoniacal and nitrate nitrogen values may be used, and correctly so, without further change.

The wire screen is washed and brushed and the excess water shaken off. It is then ready for use again without further drying.

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(2) ————, 1937. Soil and plant material analyses by rapid chemical methods—II. The Hawaiian Planters' Record, 41: 135–186. (Agric. and Chem. Series Bulletin No. 51.)

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 20, 1941, TO SEPTEMBER 3, 1941

Date	Per pound	Per ton	Remarks
June 20, 1941.....	3.525¢	$70.50	Puerto Ricos, 3.50; Philippines, 3.55.
July 3.....	3.45	69.00	St. Croix; Puerto Ricos.
" 18.....	3.47	69.40	Puerto Ricos, 3.46, 3.47, 3.48.
" 21.....	3.45	69.00	Puerto Ricos.
" 23.....	3.5267	70.53	Puerto Ricos, 3.51, 3.52, 3.55.
" 24.....	3.55	71.00	Puerto Ricos.
" 28.....	3.58	71.60	Puerto Ricos, 3.57, 3.59.
" 29.....	3.60	72.00	Puerto Ricos.
" 30.....	3.625	72.50	Puerto Ricos, 3.60, 3.65.
Aug. 1.....	3.65	73.00	Puerto Ricos.
" 6.....	3.715	74.30	Puerto Ricos, 3.70, 3.73; Cubas, 3.73; Philippines, 3.73.
" 7.....	3.75	75.00	Cubas.
" 11.....	3.80	76.00	Puerto Ricos.
Sept. 3.....	3.50	70.00	Puerto Ricos.

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